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THE ANNALS OF APPLIED BIOLOGY

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THE ANNALS OF APPLIED BIOLOGY

THE OFFICIAL ORGAN OF THE ASSOCIATION OF ECONOMIC BIOLOGISTS

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FRIT FLY (*OSCINUS FRIT*) ATTACKING WINTER WHEAT.

BY F. R. PETHERBRIDGE.

(*School of Agriculture, Cambridge.*)

From enquiries sent in during the past three years, there is little doubt that in addition to the damage it does to late sown spring oats, the "frit fly" must also be reckoned as a pest of winter wheat in this country. Several observers have recorded this fly as attacking winter wheat on the continent.

The first enquiry was received in March, 1914, from Mr C. J. Littlewood, Whitwell Hall, Skeyton, near Norwich. Specimens of dead and dying wheat plants were sent in and in these the larvae of the "frit fly" were found. Unfortunately the wheat was ploughed in just after the plants were sent, but this will serve to show that the damage done must have been considerable. This wheat was sown about December 1st.

On March 1st, 1915, an enquiry was received from Mr H. V. Sheringham, Blue Stone Farm, South Creake, Norfolk. Here 54 acres of wheat were sown on November 11th—15th, receiving a dressing of farmyard manure, and following a crop of Rye Grass and Clover. Mr Sheringham writes as follows: "The wheat was slow in coming up owing to excessive rain." Although about 20 % of the plants were attacked by the larvae of the "frit fly" the wheat tillered well in the spring and produced a fair crop (about 32 bushels per acre).

In 1916, an enquiry was received from Messrs Tayton, White Hall Farm, Syderstone, Norfolk, concerning fields quite near to Mr Sheringham's farm.

Three fields were badly attacked by the larvae of the "frit fly," their previous cropping being:

	1911	1912	1913	1914	1915	1916
32 acres	Oats	Turnips	Barley	Italian Rye Grass and Suckling Clover	Seeds mixture left down	Wheat
48 ,,		Wheat	Turnips	Barley	Perennial Rye Grass and Red Clover	Wheat
12 ,,		Wheat	Turnips and Kale	Barley	Italian Rye Grass and Suckling Clover	Wheat

The wheat was sown on Oct. 14th—20th and received 10 loads of farmyard manure per acre.

On all these fields about 25 % of the plants were attacked when examined on February 9th. No attack of "frit fly" was noticed in the spring corn of 1915.

Neighbouring fields of wheat were visited and "frit fly" larvae were found in all cases.

A field of rye joining a field of badly attacked wheat was apparently free from "frit fly."

In December, 1912, and January, 1913, Edmunds[1] found "frit fly" larvae in Rye Grass in a clover ley and also in Golden Oat Grass (*Avena flavescens*) and in False Oat Grass (*Arrhenatherum avenaceum*).

Baranov has also recorded the spring generation of flies as laying eggs on the following grasses: *Phleum pratense, Alopecurus pratensis, Lolium perenne, Triticum cristatum, Festuca pratensis, Avena flavescens* and *Poa pratensis.*

The writer also found "frit fly" larvae on Italian Rye Grass (*Lolium italicum*) on March 6th, 1916.

In this connection it is interesting to note that the above attacks are all after crops of Rye Grass or Italian Rye Grass.

The 18 acre field was ploughed up on May 1st—3rd and sown with Barley on May 4th which on threshing showed a yield of 36 bushels per acre. The other two fields were left and yielded about 20 bushels of wheat per acre. It will be seen from this that the "frit fly" is capable of causing a considerable reduction in the yield of winter wheat.

On February 21st, 1913, a sample of Winter Oats and Vetches was received from Wickham Market, Suffolk, and in the Oats larvae of the "frit fly" were found. This crop followed a crop of late-sown spring oats and was sown on October 12th.

The above observations are interesting in connection with the life history of the "frit fly."

Mr Littlewood's wheat was sown about December 1st and Mr Sheringham's wheat which was not sown until November 14th was slow in coming up. If the "frit fly" has only three broods in a year we should have expected the wheat to be safe from an attack under these conditions. Is this attack of winter wheat caused by the third brood of flies which hatch out from the pupae in the ears of oats or from those in the shoots of cereals or grasses (usually in September), or is it a fourth brood? In this connection the following may be of interest:

---

[1] *Joint Report, Harper Adams College,* 1912.

In a sample of spring wheat from Chaul End, near Luton, sown the third week in April, 1916, three larvae and two empty pupa-cases of the "frit fly" were found on October 3rd. (Other larvae very similar to those of "frit fly" but not yet identified were also found.) This crop was also badly attacked by the "Hessian Fly" *Cecidomyia* (*Mayetiola*) *destructor* and a number of young tillers were present as is usual in late-sown spring wheat.

Hitherto three broods of the "frit fly" have been recognised.

Brood 1 appears in April and May and lay their eggs on spring corn.

Brood 2 appears in July and lay their eggs on the ears of oats or barley or on the shoots of cereals and grasses.

Brood 3 appears in August and September and lay their eggs on the shoots of grasses or *early-sown* winter corn.

Without further knowledge of the life history it is difficult to account for the above attacks on winter wheat.

Among the possibilities which would account for these late attacks of winter wheat are the following:

(1) The third brood of flies may hatch out over a very long period and the last ones lay their eggs on winter wheat.

(2) Some of the third brood of flies may be capable of living until December before laying their eggs.

(3) The larvae of the third brood of flies may under certain conditions give rise to a fourth brood of flies which lay their eggs on winter wheat.

(4) In a letter Fryer suggests that "The third brood of flies may migrate from the plants on which they hatched to the wheat which is sown after the former host plants are ploughed in."

Cases 1, 2 and 3 seem rather improbable as it would necessitate the emergence of the fly in cold weather of which at present there is no record.

Case 4 seems more probable as several observers have found "frit fly" larvae in the shoots of grasses and it is quite possible that migration takes place from these plants to the wheat. This would also account for the absence of the adult fly in the winter months.

It will be seen from the above that more knowledge of the life history of the "frit fly" is needed in order to find out the most efficient means of reducing attacks on winter wheat. We know that early-sown spring corn in a good seed bed usually escapes attack, but as the fly can lay its eggs on grasses there is always the danger that our winter wheat will be attacked even if we sow our spring corn early.

SOME FARM INSECTS OBSERVED IN THE ABERYSTWYTH AREA, 1913–1916.

By C. L. WALTON, M.Sc.

(*Departments of Agriculture and Zoology, University College of Wales, Aberystwyth.*)

The following insects were collected and observed during the progress of a Survey of Agricultural Zoology which I recently carried out in the Aberystwyth Area.

The area examined comprised some 250 sq. miles, and included the Plynlymon mountain mass; the wooded river valleys and foot hills; the wide peat bog bordering the southern bank of the Dyfi Estuary; the cultivated region of hill and valley about the coast and lower reaches of the rivers Rheidol and Ystwyth; and a region of high, bare, ill-drained hills (largely coated with boulder clay) lying to the S.E. and within the Teifi watershed. The predominant features of the whole include slaty and grit rocks, overlaid to a very large extent by peat and boulder clay; a moist climate; an Agriculture in which sheep farming predominates, followed in order by cattle raising, dairying and horse breeding. Corn and root growing are seldom more than subsidiary in value; while fruit growing hardly exists; and market gardening, to a limited extent, around Aberystwyth only.

During the progress of the Survey little attention was paid to any gardens other than those of the farmers, and in the mountains few farms can boast a garden worthy of the name. In many groups the lists are by no means complete, the scope of the Survey was a wide one, and special attention was given to the Liver Rot of sheep. The work was carried out under a grant from the Board of Agriculture and Fisheries.

Cabbage Butterflies.

Early in September, 1914, I left Aberystwyth and travelled down the coast of Cardigan Bay (chiefly on foot) into Pembrokeshire and visited several parts of that county. Up to the time of leaving the Survey

Area I had not received any complaints or noted any unusual abundance of the larvae of the White Butterflies, and my attention was first drawn to an attack upon Swedes and Rape in adjacent fields upon a cliff farm near Fishguard. Subsequently I saw others, while Cabbages were, in many places reduced to mere skeletons. I returned to Aberystwyth by train and noted some damaged Swedes as soon as the Survey Area was entered. I made about 40 enquiries, and discovered that whilst not so severe as in S.W. Wales, these pests were sporadically abundant within the Area. Following these enquiries I visited a number of the places whence damage was reported.

The larvae of *Pieris brassicae* and *P. rapae* damaged garden Crucifers, and to a lesser extent Swedes from sea level to 1100 feet. The damage to Broccoli and Sprouts, however, was not equally distributed; steep banks lying in the sun; the upper parts of fields and similar hot, dry situations suffered most, while gardens and fields in damp situations, near rivers, etc., were least affected.

Two of the more severe cases were reported from mountain valleys; one from the upper portion of the Ystwyth (about 700 feet) following a swarm of butterflies which were noted about the Swedes at the end of August; the other from the steep slopes of the Rheidol valley. This latter was visited when the Swedes were being harvested, and there was little difference in size between the roots from the upper half of the field which had been badly stripped, and the lower which was but lightly attacked, the damage having being done too late to seriously affect growth. Both in Pembrokeshire and in the Aberystwyth Area farmers reported that broadcasting lime and soot had been without effect. Within the Survey Area one farmer tried dusting with Basic Slag after a shower (on Swedes) and another had no success with a dressing of Baking Powder applied to cabbages!

Mr D. J. Morgan the Agricultural Organiser for Cardiganshire informed me that he had observed Keating's powder (Pyrethrum) used upon Cabbage with excellent results. Commencing on September 28th I experimented upon several rows of Cabbages in an Aberystwyth garden; dusting with lime produced little results, and watering with brine practically none, but a dusting of Pyrethrum was rapidly effective.

A large proportion of the larvae in Aberystwyth gardens were parasitised, and quite half the larvae and pupae observed attached to walls, etc., in early October showed the yellow cocoons of the Braconid, *Microgaster glomeratus*.

During September and October, 1915, I noted slight damage to

Swedes in two instances, in each case the margins of the fields being affected, but no serious outbreak followed the unusual abundance of 1914.

In 1916 a number of the larvae of *P. brassicae* were present upon Swedes near Crosswood at the end of July, and upon Cabbage in gardens during September, and the parasite above mentioned was again in evidence, especially about Aberystwyth.

FLEA BEETLES.

I received fifty complaints of damage to root crops by Flea Beetles and investigated a large number of these.

Two species are present, *Haltica nemorum* and *H. oleracea*. The former is generally the more abundant and at times is locally predominant, but usually both are present, and often in about equal proportions. These pests appear to be always present, and only await the advent of the needful crop and weather conditions in order to multiply and work havoc. Dry weather and sunshine are essential to these beetles and heavy rain either ends, or very much limits their ravages.

Young root crops on dry slopes, hillsides and banks are usually the worst damaged, but I have seen considerable harm done in low fields as well.

Should adverse conditions delay growth the damage done is generally aggravated, the continuance of conditions favouring the pests may result in the first sowing of seeds failing entirely, while even a second may be damaged.

It is notable that comparatively few complaints are heard from farms where lime and basic slag are regularly used. On many farms it is usual to give a dressing of quick lime prior to sowing the root crop.

During July, 1915, I noted a slight attack on mangolds. The situation was high and sunny, and it was evident that the Swedes having made a very vigorous growth, the beetles had migrated to the contiguous rows of mangolds, of which, however, only the two nearest rows were affected. In 1916, mangolds were severely attacked, and in a number of instances the crop was considerably reduced. In one case roots had not been grown upon the field within local memory, two crops of oats having followed an old rough pasture, prior to the root crop. Damage continued in this field up to mid July, and included successively mangolds, swedes and turnips. *Polygonum persicaria* was a common weed in this field (and often abounds in mountain root fields) and was also badly riddled by the beetles.

Soaking seed in paraffin has proved of benefit. One farmer broadcasted basic slag upon a badly infected patch without obvious benefit and two others remembering the customs of their grandfathers dragged branches of Elder (Ysgawn) over their fields, but, as one of them said, "only made 'em hop."

Apple Weevil, *Anthonomus pomorum*, Lin.

The Apple Weevil occurred in some abundance in May, 1914, upon apple blossom in a farm garden three miles S. of Aberystwyth. A considerable number of apples had been planted about the house and buildings and latterly somewhat neglected. The beetle was also present upon crab apples in the same vicinity, but whether the pest was introduced with the apples or was endemic upon the crabs it is not possible to say; but probably the former. I have since found this weevil in one or two other gardens, all far apart.

Clover Weevil, *Apion apricans*, Herbst.

The Clover Weevil was seen in some abundance in July, 1916, among hay crops when being harvested, near Crosswood, and several were obtained on pasture fields while gathering mushrooms in September in the same locality.

Wireworms, *Agriotes* sps.

Thirty-two farmers and several gardeners complained of wireworm attack in varying degrees of severity. Oats, wheat, swedes and potatoes were the crops involved, but principally oats and swedes.

As mentioned under flea beetles, farmers who make a free use of lime, basic slag, kainit, etc., seldom complain of these larvae. Almost all the worst attacks were in the second successive crops of oats following old, and often "foggy" pastures; the damage to the first crop being either slight or not recognised, and there is no doubt that many of these outbreaks could be avoided, by care and observation.

The majority of the affected fields are situated on sunny hill-sides, where the soil is shallow and dry. Many of the complaints (and almost all relating to swedes) came from the S.W. region of the Area surveyed, —named by myself the "Coastal Uplands," and most of the cases of young swedes being pulled up by rooks are due to the energetic search for the larvae by these birds.

Notwithstanding the abundance of the larvae, I have found it difficult to obtain more than odd specimens of the adult beetles and hence cannot say anything about the relative distribution of the species.

Several farmers harrowed in a dressing of soot and subsequently rolled, with excellent effect, while both kainit and lime have proved their value.

On some farms about 15 cwt. per acre of ground lime mixed with the surface soil during the preparation for roots, helps greatly to clear the land of these pests.

Plain rolling, although doubtless of assistance, seldom effects a cure on the light stony soils.

One farmer experimented with plots as follows:

1. Rolling every other day.
2. Applied soot and then rolled.
3. Applied salt and rolled.
4. Applied a dressing of nitrate of soda.

No. 2 proved most effective, followed in order by 4. This man noted a daily advance of two yards by these larvae, he now controls any patches that appear by the use of soot, harrow, and roller.

The value of basic slag in controlling *Agriotes* larvae was noted by Umnov in 1914. Part of a field manured with superphosphate was injured, while a neighbouring part manured with basic slag was not attacked[1].

CHAFER BEETLES, *Phyllopertha horticola*, Lin., etc.

I have never seen a single specimen of the common Cockchafer (*Melolontha vulgaris*) within the Area, except about the town of Aberystwyth; and of *Cetonia aurata*, the Rose Chafer, one complaint of damage to rambler roses reached me. From the appearance of the foliage and the description given it is probable that that insect was the cause.

P. horticola. The so-called Garden Chafer, however, is locally exceedingly abundant at times. It is typically an inhabitant of the "slope land," and swarms about the dry sunny sides of the mountain valleys. The adults were very abundant in June, 1915, especially in the Northern valleys, and in August—September the larvae abounded in the pasture lands of these slopes. Rooks and other birds assembled upon these places in hundreds and in their search for the grubs literally dug up acres of the already loosened herbage. Notwithstanding their efforts a considerable number of larvae remained; but there is no doubt that this Chafer is largely controlled by these birds. Further examination in March and September, 1916, showed that these pastures had largely recovered by the latter date. I have heard the term *Chwilen y rhedyn* or fern beetle applied to this insect in the Llyfnant Valley, where also I was informed that it had damaged garden apples.

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[1] A. Umnov. Report on the Work of the Entomological Bureau of Kaluga, 1913. (Abstract from the Russian, in *Review of Applied Entomology*, April, 1914.)

APHIDES.

I am indebted to Prof. F. V. Theobald, M.A., of the South Eastern Agricultural College, Wye, for the identification of all the species here recorded with the exception of *S. lanigera*, *R. ribis* and *M. cerasi*. Apart from these and *A. rumicis*, none are of economic significance agriculturally.

With regard to the above species *Rhopalosiphum ribis* is seldom common and little fruit is grown in the Area apart from private gardens.

Aphis rumicis sometimes occurs in numbers upon mangolds, and in 1915 I noted it abundantly upon *Atriplex patula* growing among mangolds on July 1st. A watch was kept, but none were observed upon the mangolds until July 7th when migration commenced. In 1916 this pest was scarce, and I only obtained a few from Docks in July and August, and a very few on Broad Beans in early September. This species was so abundant upon Broad Beans in 1915 that a large proportion of the crop failed completely, the plants presenting a stunted and scorched appearance. Beans are not grown as a field crop within the Area, only a few rows being seen, here and there. Even in gardens the practice of "topping" is practically unknown, and hence no check is given to the pest. During 1916 this insect was also as infrequent on beans as on mangolds.

Macrosiphum granarium was found upon black oats near Crosswood during July, 1915, but not in sufficient abundance to make any difference to the health of the crop.

Schizoneura lanigera. This species is to be found practically wherever apples are grown but generally in small amount. With certain exceptions, the farmers of the Area give but little attention to gardening, especially those living at high elevations. Market gardening could, in certain parts, be practised to a much greater degree.

The following is a list of recorded species, together with their host plants:

Phylloxera quercus, Fons. Oaks in hedge, abundant at Crosswood, Aug. 1916.

Schizoneura lanigera, Hausmann. Apple.

Callipterus quercus, Kaltenbach. Crosswood, 1915. Collected on Oats, but probably came from an Oak near by.

Aphis pruni, Reaumur. Damsons.

A. rumicis, F. Beans, Mangolds, Docks and *Atriplex*.

A. cardui, Lim. *Carduus arvensis*. 1916.

A. urticaria, Kalt. Nettles. Crosswood.

A. loti, Kalt. *Lotus* sp. Crosswood.

A. gossypii, Glover. A Cucumber grown in the open was killed by this insect. Crosswood, July, 1916.

A. hederae, Kalt. *Aralia sieboldii*. Aberystwyth.

Rhopalosiphum ribis, L. Garden Currants.

R. lactucae, Kalt. *Sonchus oleraceus*.

Macrosiphum rosae, L. Rambler Roses, also on Dog Rose in hedges.

M. jaceae (L.). *Centaurea niger* and *Lychnis diurna*.

M. lactucae, Kalt. Lettuce. Aberystwyth.

M. granarium, Kirby (*M. cerelis*, Kalt). Oats, July, 1915.

M. absinthii, L. Wormwood. Crosswood, July, 1916.

M. pseudorubiellum, Theobald. Brambles. Crosswood, July, 1916. A species recently described.

Myzus cerasi, Fabricus. Cherry (on wall). Llanfarian.

M. circumflexus, Buckton. Cineraria. Pontrhydgroes.

Amphorophera rubi, Kalt. Brambles.

Also several others not yet correctly determined.

SCALE INSECTS.

Scale insects are not at all common within the Survey Area, with the exception of *Chionaspis salicis*, L., which is common upon Ash, Birch and various species of Sallow (*Salix*) from sea level to the upward limit of the tree growth.

Lepidosaphes ulmi (*Mytilaspis pomorum*) is to be found in some gardens, but very seldom in any abundance. It does not occur in such a manner as to suggest that it is native in the Area, and would appear to have been introduced with nursery stock. It was abundant on apples in one garden in Aberystwyth and upon a pear trained against a wall in another. Elsewhere it only occurred in very small numbers and then usually upon young isolated trees.

Lecanium persicae (Geoffrey) has been sent me twice from private gardens and *L. capreae* (L.) once from a similar situation.

Nine species were obtained from indoor and green-house plants chiefly about Aberystwyth and the experimental green-house of the Botany Department of the University: these nine were as follows:

1. *Aspidiotus hederae*, Vallot. On a pot palm.
2. *A. cyanophylli*, Signoret. Leaves of *Cycas revoluta.*
3. *Fiorinia fioriniae*, Targioni-Tozzetti. Palm, with *A. hederae.*
4. *Diaspis zamiae*, Morgan. Upon ♀ sporocarp (megaspore) of *Dioon edule.*
5. *Chionaspis aspidistrae* (Signoret). Ferns.
6. *Lecanium hesperidum* (L.). Common upon pot ferns.
7. *L. perforatum* (Newstead). Palm.
8. *L. hemisphericum* (T. T.). On *Macrozamia spiralis.*
9. *Dactylopius longispinus* (T. T.). Vines; beneath scales of *Cycas revoluta*; and larvae beneath leaves of *Dorstenia* sp.

CECIDOMYIDAE.

Only two have been noted as harmful.

Perrisia crataegi (Winn), which affects the tips of young Hawthorn shoots causing them to assume the appearance of a rosette. This insect is common, and affects a considerable proportion of the shoots in the lowlands.

The second species is *Rhabdophaga salicis* (Schrank) which I have obtained galling species of *Salix* on the banks of the Ystwyth, near Aberystwyth, and elsewhere; it is not at all abundant.

CRANE FLIES, *Tipulidae.*

I have only recorded three species, although others undoubtedly exist, one of which was very abundant on the Dyfi Flats in 1914; the specimens then collected were, however, unfortunately lost. *Tipula oleracea*, Lim., is at times very common, but only one complaint concerning it reached me, specimens being sent in 1913 by Sir E. Pryse, Bart.; the larvae were exceedingly abundant in one of his fields at Gogerddan. *T. lateralis*, Meig., was fairly common in 1916, and *Pedicia rivosa*, L., was obtained on mountain pastures.

ONION FLY, *Phorbia cepetorum,* Bouché.

The Onion Fly was noted several times from leeks. In October, 1915, in a farm garden near Borth, a bed of leeks 40 × 15 feet in extent was destroyed, only about a dozen plants remaining when I visited the place on November 4th. From 3 to 7 larvae were obtained from each of these leeks.

MANGOLD FLY, *Pegomyia hyoscyami*, Panz. (*P. betae*, Curt.).

The Mangold Fly. I have never seen young Mangolds attacked, nor any appreciable damage done, but a few brown blisters are to be seen now and again. I have failed to obtain the adult fly.

PIOPHILA CASEI.

I observed this fly in hundreds in one farm house, and obtained the larvae from bacon and hams that were hanging from the ceiling of the kitchen. These maggot-like larvae can "skip" freely, and do not seem to harm the bacon to any great extent, since no foul or decayed place could be found even where the larvae were feeding.

LIPURA AMBULANS, L.

This minute Apterous insect was observed in November, 1915, in large numbers upon leeks in a farm garden near Borth. The leeks had been very severely attacked by the Onion Fly (*P. cepetorum*). Some adjacent carrots were also attacked, but were not seriously injured. The same pest was obtained damaging the seeds of French Beans sown in an Aberystwyth, garden in the Spring of 1916. *Sminthurus luteus*, Lubbock, was fairly common upon field mushrooms at Crosswood in September, 1916. Several other related species were observed in small numbers.

ANTS.

Time did not allow of a full study of many groups of subsidiary interest, and I am chiefly indebted to Mr F. S. Wright of the Zoology Department, Aberystwyth, for the following identifications of Ants collected during the course of the Survey.

The nomenclature is that of Donisthorpe, *British Ants*, 1915.

1. *Monomorium pharaonis*, L.
2. *Myrmica laevinodis*, Nyl.
3. *M. ruginodis*, Nyl.
4. *Formica rufa*, L.
5. *F. fusca*, L.
6. *F. rufibarbis*, F.
7. *F. picea*, Nyl.

All the above records refer to workers.

F. fusca seems to be the most widely distributed, and has been taken from sea level to 1000 feet.

M. pharaonis was only obtained from the town of Aberystwyth where it was causing annoyance in a bakery and also in a tobacconist's shop.

F. rufa is confined to woodlands containing an admixture of Coniferae.

WASPS.

These insects are usually fairly abundant, but were peculiarly scarce in 1916, although queens were plentiful during the spring and I obtained specimens of *Vespa vulgaris*, *V. germanica*, and *V. rufa*; the two former commonly. Old nests of *V. sylvestris* have been observed but I have not taken the insect.

HUMBLE BEES, *Bombi*.

I am indebted to Mr T. Alan Stephenson for the following notes on the *Bombi* and *Psithyri* of the Aberystwyth Area.

At my suggestion he gave considerable attention to these groups during 1915–16.

Twelve species of *Bombus* and five of *Psithyrus* have occurred, namely:

1. *Bombus lapidarius*, Linn.
2. *B. terrestris*, Linn.
3. *B. lucorum*, Linn.
4. *B. soröensis*, Fab.
5. *B. pratorum*, Linn.
6. *B. jonellus*, Kirby.
7. *B. lapponicus*, Fab.
8. *B. hortorum*, L.
9. *B. derhamellus*, Kirby.
10. *B. sylvarum*, L.
11. *B. agrorum*, Fab.
12. *B. helferanus*, Seedl.

1. *Psithyrus rupestris*, Fab.
2. *P. distinctus*, Perez.
3. *P. barbutellus*, Kirby.
4. *P. campestris*, Panzer.
5. *P. quadricolor*, Lepeletier.

Of these, *B. agrorum* is the most abundant and widely distributed species, while *lapidarius*, *lucorum*, and *hortorum*, are almost equally common.

B. sylvarum and *helferanus* are fairly frequent; while *terrestris*, *pratorum* and *soröensis* are scarce. *B. jonellus* only occurred two or three times; while of *derhamellus*, three queens have been taken, and of *lapponicus* a single male only.

Of the *Psithyri* the most abundant is *campestris*, which preys upon *B. agrorum*: *P. barbutellus* is fairly frequent, as one would expect from the fact that it is parasitic on *B. hortorum*. *P. rupestris* is more frequent than *barbutellus*, while of *distinctus* two queens have been obtained, and of *quadricolor* one only.

THE HONEY BEE, *Apis mellifica*.

The Isle of Wight disease has caused serious loss around Aberystwyth during the course of the Survey. Commencing apparently near the town, it rapidly spread and involved several flourishing apiaries, and has so far extended its ravages some 2½ miles beyond the town. Thanks probably to their isolation, the country bee keepers so far remain unaffected, and it is greatly to be hoped that the disease has reached its limits. Apart from this scourge, local bee keepers have little to complain of and would do well. The usual bee pests, Wax Moth, *Braula caeca*, etc., are present but not in excess. The Blue Tit is responsible for taking a few bees.

NEMATUS RIBESII Scop.

The Gooseberry Sawfly was fairly common in farm gardens in 1914, and was noted as high as 800 feet at Pont Erwyd. In a garden near Llanfarian the larvae appeared about April 25th and I noted a second brood there by June 20th, when, also, Red Currants were attacked adjoining the Gooseberries, although plenty of foliage still remained upon the former.

Finally, the following Mites may be mentioned.

ERIOPHYES RIBIS Nalepa. *E. AVELLANAE* Amerl.

The first of these two bud mites occurs sporadically in gardens. *E. avellanae* is common in Hazels on hedgerows.

Tyroglyphus longior, the Hay Mite, was sent me from Pembrokeshire where it was destroying an Oat rick; and another correspondent sent specimens from feeding stuffs in N. Wales.

T. siro was found feeding upon the crystallised sugar on the top of a jar of jam, Aberystwyth.

A NOTE ON AGRICULTURAL OECOLOGY IN MID-WALES.

By C. L. Walton, M.Sc.

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During the progress of the Survey of Agricultural Zoology which I recently carried out in the Aberystwyth Area, some interesting and instructive inter-relations between wild and domesticated animals were noted.

The more natural conditions prevailing over large portions of Mid-Wales permit such interaction to be noted with greater readiness than would be the case in closely cultivated areas, where conditions are more controlled.

In the instances about to be given the main factors are:

(1) The distribution of the rabbit, which depends largely upon the physical conditions, and human control (which affects their relative abundance).

(2) The Sheep Industry, which is profoundly under the influence of the local custom of transhumance, involving the movement, twice yearly, of great numbers of sheep between upland and lowland.

(3) The abundance of foxes (a condition again somewhat influenced by the War).

(4) The number of sheep dogs kept; often excessive and insufficiently controlled.

In addition to the above are:

(5) The Poultry Industry.

(6) Hunting.

(7) The Sheep disease "Gid," due to the cysts of the parasitic Tape Worm *Taenia coenurus*, of which the hosts are the dog and the sheep.

(8) The distribution of the polecat, which is closely linked with that of the rabbit.

These two last are quite subsidiary and only included to show the complexity of the local animal inter-relation. My attention was drawn to these conditions through the complaints of farmers, shepherds, and poultry keepers, regarding serious losses of lambs and poultry, due to foxes.

The physical features of the area dealt with include the wide, open, grassy and peaty uplands of the mountain complex of which Plynlymon is the centre; the foot hills and river valleys often rough and wooded; the cultivated and fertile lowland and coastal region, and the large peaty tract bordering the Dyfi estuary and known as Borth Bog, or the Dyfi Flats.

On the mountains the sheep receive relatively little attention, and the amount of necessity depends very largely upon the size and nature of the holding or "walk," the number of sheep, and the persons responsible for their care. Even if more or less tended by day, the sheep are exposed to any danger that may threaten them during the night and early morning. The condition of affairs here described may possibly apply, with some modification, to other mountain areas.

During the progress of the survey I received 70 complaints of damage to lambs and poultry by foxes, and it would have been easy to add largely to that number if farm visiting had been continued on the same scale in 1916 as in the previous years. The complaints, as indicated above, fall under two heads:

(*a*) lambs, (*b*) poultry, and these must be considered separately.

Foxes are common in the area, and are hunted by the pack of hounds kept by Sir Edward Pryse, Bart., at Gogerddan, near Aberystwyth, about the centre of the area. This pack has not, of course, hunted to the same extent since the outbreak of War, and foxes seem to have increased both in numbers and boldness.

A second pack has quite recently been started on the southern side of the area. Cubs were reared, and poultry raided even in the town of Aberystwyth, and many foxes were perforce destroyed by farmers and others throughout the area in sheer self-protection. The chief losses of poultry are, of course, practically confined to the lowlands and valleys, few poultry being kept at higher elevations, and in addition to the direct loss there must be added the discouragement of poultry keepers. Part of the loss is due to bad management, and careless housing of fowls due to slackness on the part of the poultry keepers, and partly owing to lack of suitable places in which to house them. The loss of lambs occurs chiefly in the mountains, and in certain districts is serious.

That much of the loss is due to foxes is certain, but I do not consider that the whole of the damage attributed to them can be laid to their account.

Dogs are responsible for a considerable share, and often I believe the dogs of the farmers themselves, though many are unwilling to admit it. Dogs are left loose in some instances with a view to protection from foxes. It is my opinion that too many dogs are kept on many of the farms and sheep walks, and very frequently these are not sufficiently well fed. Quite a number of outbreaks of lamb killing have been traced to dogs (and some of these were destroyed) during the progress of the Survey, but it is unlikely that I have heard of more than a part of the total.

Again, these dogs, and others, are very seldom kept shut up at night, and a considerable proportion roam the hills at will. When stopping here and there in the hills during the course of the Survey I have been disturbed during the nights by such prowling dogs. It would no doubt be difficult to track many, but the practice is very harmful in this and other connections. Nevertheless, although some part of the total loss is attributable to dogs, the fact remains, that a heavy and unnecessary toll is taken by foxes at the expense of sheep farmers. Complaints of loss vary from four or five lost to 40 or 45, and in the spring of 1913, one group of eight sheep walks together claim to have lost 300 lambs. The most dangerous period in the hills is usually May, when thousands of ewes and lambs are taken from the lowlands to the mountain walks for summer grazing. A proportion of ewes are lambed on the sheep walks, in some cases depending largely on the elevation and the amount of improved land available.

If a map is constructed showing the distribution of these troubles it will be noted that a very considerable proportion of the complaints of loss come from the hill country lying W. of Plynlymon, and more or less in the centre of the Survey Area, and further that it comprises the hinterland of the region most hunted. Another point of great importance shown by mapping is the distribution of rabbits within the area. It will be observed that very few rabbits occur in this region showing the greatest damage to lambs, in marked contrast to the state of affairs in the southern part of the area. There is no doubt that foxes everywhere depend very largely upon rabbits for their food, and in these hills rabbits are either very locally distributed or quite absent. Moreover it so happens that the maximum number of lambs are available just when the vixens have to feed their cubs and teach them to hunt;

and finally, it is contended by some that hunting in the lower lands drives lowland vixens into the hills and so further accentuates the coincidence of circumstances which cause trouble. I have myself examined lambs found dead, and partially eaten, upon the sheep walks in that region, and consider their deaths were due to fox attack.

A minor annoyance due to foxes is the manner in which they tear and mutilate rabbits caught in traps and snares. Foxes are made aware of the whereabouts of such rabbits by their cries when first caught. A curious custom, the origin of which is obscure to me, is that of putting raddle or red paint upon the back of lambs, to keep off foxes. Another local idea is that foxes show a preference for white fowls; and this may be explained perhaps by the greater prominence of such birds at night, etc.

One farmer says that he has observed foxes catching moles, digging them out as dogs sometimes do.

Rabbits are particularly abundant along the coast region between Aberystwyth and Borth, and also in the valley of the Ystwyth; but comparatively few complaints as to damage have been made to me. This is possibly due to the amount of rough land and the wide range they usually enjoy, for very seldom does a colony occupy narrow limits surrounded by cultivated land. In certain cases, however, I have seen considerable damage to young corn, and also to meadow grass. Throughout the remainder of the lowlands and slope lands rabbits are usually present in small numbers, but on the mountain tops they are very scarce, or entirely absent, especially on peat. There are several interesting exceptions; in one instance at an altitude of 1300 feet, a colony is established in a fir plantation, three miles from any other colony of which I am aware.

The other exceptions are due to the physical characters of the Drosgol Grits, which weather into rough screes formed of blocks of stone that provide shelter for rabbits from whence it would be extremely difficult to dislodge them. I am aware of three such isolated colonies, two at 800—1000 feet, and the other at 1200—1600 feet. From what I can gather, certain changes have taken place in the local distribution of recent years; in two districts a reduction in numbers is apparently due to persistent trapping, etc., but in another to a severe outbreak of Coccidiosis (*Eimeria stiedae*), which disease I have several times observed. I have not been able to obtain any rabbits suffering from Liver Rot, but several farmers informed me that during recent outbreaks they observed flukes in the livers of rabbits killed on their farms. A liver containing a very considerable number of flukes was sent me from Mid-Pembrokeshire in 1913.

The distribution of the Polecat (*Mustela putorius*), which is by no means uncommon in North Cardiganshire, seems to be largely governed by that of the rabbit, upon which it largely preys. The polecat is now and again responsible for some loss to poultry keepers. I conclude therefore that foxes are over abundant in the area, and, as elsewhere, are a needless source of loss to sheep farmers and poultry keepers. In rough country it is always difficult for the hunt, however well intentioned, to kill all troublesome foxes, and the more their numbers increase the greater becomes the difficulty of the chase. The present over abundance will doubtless, to some extent, be dealt with by the sufferers. As regards the dog problem, although sheep farmers claim that large numbers are needful in order to work their widely-ranging flocks, I nevertheless consider that a diminution in their number, coupled with a greater control and better feeding and attention in some cases, would result in a reduction of trouble, and also in the number of young sheep suffering from "Gid." There will probably always remain enough foxes to provide sport for the hunting people.

Rabbits again could with advantage be reduced in numbers in certain districts, and land given up to them utilized to better purposes. On the whole they can usually be readily controlled within the area under consideration.

A general account of the Mammals of North Cardiganshire will be found in a paper by Mr F. S. Wright, in the *Zoologist* for September, 1916.

ON A DISEASE OF THE BEECH CAUSED BY *BULGARIA POLYMORPHA* WETT.

BY R. J. TABOR, B.Sc., AND KATE BARRATT, M.Sc.

(*From the Department of Botany of the Imperial College of Science and Technology, London.*)

(With Plate I.)

During the last few years, a number of the pollard beech trees at Burnham Beeches have suffered from a disease which has apparently caused the death of several specimens, and is seriously affecting some others. The symptoms of the disease are very marked. At various points on the surface of the bark a brown liquid exudes which rapidly concentrates to a dark viscous gum[1], collecting in gouts near the point of exit and, if in quantity, trickling down to lower levels. The material is partially soluble in water, with the result that in wet weather it is washed down and may be thus distributed over a considerable area of the lower part of the trunk. The effect is very unsightly and the trees attacked are readily detected (Fig. 1). Frequently the gum provides a medium for the growth of various saprophytes, yeast, bacteria, moulds, etc., and then becomes of a creamy consistency and buff or pinkish in colour.

The effect on the tree is very serious. The bark from which the gum proceeds is already dead, and since the affected areas are often rapidly extended, the life of the tree may be seriously threatened.

These pollards are probably some of the oldest beeches in existence. Their life has been prolonged far beyond what is generally regarded as the normal limit of the species by the systematic pollarding, which—as was usual in ancient forestry—was done at such a height as to protect the young shoots from browsing animals. The cessation of cutting, however, permitted the growth of a few of the more favoured shoots and the trees now bear several fine limbs rising from the crown.

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[1] This substance has been referred to throughout as gum, though its exact nature has not yet been determined.

It is obvious that pollards are particularly exposed to the attack of parasites which can obtain an entrance and destroy the heart wood, and these old beeches are in most cases nothing but hollow shells. The outer wall of wood and bark has also suffered frequently from accidental injury and disease, and is now a patchwork of dead and living tissue. In fact it is astonishing to observe in some instances, how restricted is the tract of living, conducting tissue, which connects a well-developed limb above with the root system below. It must operate as a limiting factor in the relations between the root system and the leafy canopy dependent upon it above; and it is a fact that the trees are extremely sensitive to anything which tends to disturb these relations, *e.g.*, dry seasons, clearing and felling in the immediate neighbourhood. For the same reason they demand constant attention in the matter of pruning, mulching, etc. It is obvious that any attack on these vital tracts must rapidly prove fatal, and they are particularly exposed to the ravages of facultative parasites which have established themselves on the neighbouring areas of dead tissues. Moreover diseases affecting the bark are much more rapidly fatal than those attacking the wood, since the death of the inner bark and with it the cambium, deprives the tree not only of the means for conveying its elaborated food materials, but of its capacity for forming new tissues. A number of fungi are found constantly growing on the pollards, and amongst others *Fomes fomentarius*, *Stereum hirsutum*, *S. purpureum*, *Armillaria mucida*, etc.

The Ranger, Mr M. C. Duchesne, observed that fruit bodies of *Bulgaria polymorpha*, Wett., were often abundant on trees exhibiting the gumming. The evidence of association however between the fungus and the disease was not at all convincing.

At the time our attention was first called to the disease the fruit bodies of the fungus were scarce. Trees showing the gumming often exhibited no trace of *Bulgaria*, whilst on the other hand felled logs, with the bark covered with the scars and remains of old fruit bodies, usually showed no evidence of gumming. It was possible moreover that the disease might have no connection with a parasite, but have resulted from some functional disturbance. Our attention was therefore directed not only towards the examination of the diseased bark for evidence of the presence of any living organisms which might be concerned with the disease, but also to determining whether the disease could be transmitted to healthy trees.

ASSOCIATION OF BULGARIA WITH THE DISEASE.

A number of specimens consisting of portions of wood and bark from diseased trees were forwarded for examination. They all showed a covering of gum on the surface of the bark which in most cases was dead. Examination of the bark yielded no results of any value. In one specimen only, a yellow mycelium was found between the bark and the wood. This was probably the mycelium of *Bulgaria*, but attempts to cultivate it failed. Subsequent examination of the trees from which the specimens were cut, suggested that in some instances the gum on them had trickled down from a diseased area higher up the trunk. Two specimens were placed in a damp chamber and kept under observation for about 18 months. No exudation of gum occurred from these specimens. A few saprophytic moulds appeared at first on the gum and later *Stereum hirsutum* in abundance on both specimens. In the spring of 1916 the examination of the infected trees was resumed and was confined to the careful investigation of one badly diseased tree in Victoria Avenue, Burnham Beeches. One of the two main branches of this tree had died and had been removed in the winter of 1914–15. The log showed abundance of *Bulgaria* fructifications during 1915. The remaining branch of this tree is still living and apparently healthy, but a considerable area of the bark at the base is dead and although no gumming has taken place in this region, yet infection experiments (described below) show that the same disease is in question. It was from the base of the main trunk that the specimen, referred to above as showing yellow mycelium, had been obtained. Fresh portions of bark from this region, which was gumming freely, were brought into the laboratory and on one of them a yellow mycelium appeared. This was transferred to an artificial medium and has been kept in continuous cultivation. Of the various media tried, prune agar proved to be the most satisfactory. Four weeks after the material had been collected a fructification of *Bulgaria* appeared on the bark and could be clearly traced in connection with the yellow mycelium.

Ascospores were collected on sterile cover glasses suspended over the apothecium, and were transferred to various media. They germinated readily and gave rise to a mycelium identical with that obtained from the diseased bark. Other specimens of bark brought in later also developed fruit bodies of the fungus, and portions of bark taken from other diseased trees in every case yielded the yellow hyphae. Pure cultures of the mycelium have been under observation for many months both on nutrient jelly and on sterilised bark and wood. The characteristic apothecia of *Bulgaria* have appeared in a number of the cultures, and thus complete confirmation has been obtained as to the identity of the mycelium present in the diseased bark.

Infection Experiments.

The first infection experiments were started in the autumn of 1915, before the mycelium had been found in the bark, and were directed towards determining whether the disease could be transmitted from affected to healthy trees. For this purpose, portions of bark were removed from the affected area at the base of the living branch of the pollard in Victoria Avenue. The bark was cut out, with suitable precautions, with a circular punch and transferred to holes cut with the same punch in the living bark of a healthy pollard. They were secured with grafting wax. Of the grafts made in this way, one shrivelled and cracked and fell out, and another gave no visible result, but the third examined on May 7th, 1916, showed a trickle of gum from the lower edge of the graft forcing its way through the grafting wax (Fig. 2). This exudation continued during the whole of the year. Examination of the bark around the graft showed that the gum was proceeding from the stock, and thus established the fact that the disease was communicable and certainly of parasitic nature. The difference in the behaviour of these three grafts is very probably due to the fact, that the two which failed were cut from well within the dead region of the bark, the other from the margin of the diseased area where the fungus was presumably in active growth. It may be pointed out moreover, that the absence of gumming from these unsuccessful infections resolves any doubts as to the exudation of gum being merely a traumatic response.

When later, the yellow mycelium described above had been isolated and identified, a second series of infection experiments were initiated. The same pollard on which the first experiments were made was now infected in two places on July 11th with actively growing mycelium, in one case from that obtained by germinating spores of *Bulgaria*.

The surface of the bark was cleaned and a deep cut, extending to the cambium, made with a sterilised chisel. The bark was gently levered up and a portion of agar, with the actively growing marginal hyphae from a plate culture, was inserted and pushed down into contact with the wood. The bark was then pressed back into position and the wound covered with grafting wax. At the same time two young trees were similarly infected. Three weeks later, July 31st, one of the infections on the pollard showed signs of gumming, and by the end of August they were both gumming freely (Fig. 3). Mycelium of *Bulgaria* has been isolated from the bark, though up to the present no ascophores have appeared on the tree.

On the other hand, the infections on the young trees have yielded no visible result. These same young trees were again infected with active mycelium on Sept. 27th, but without success, and they are now apparently quite free from disease.

The power of resistance to the attack of the fungus possessed by the young bark on the living trees is further exemplified by the results of experiments in the laboratory. On July 20th a series of cultures in potato dishes were established on portions of wood and bark about 4″ × 3″ taken from a young healthy branch, severed for the purpose. One half of these specimens were sterilised in the autoclave before infecting, the remainder were infected straight away with actively growing mycelium at the junction of bark and wood. The infections were uniformly successful on those specimens which had been killed and sterilised, but failed to establish themselves on the living bark, although in several instances a second infection was attempted. The results of these experiments were so significant that they were repeated on Oct. 6th. Five specimens of living bark and wood 4″ × 3″ being infected with mycelium together with five similar specimens killed in the autoclave. Four days later the fungus was spreading rapidly on the dead bark but had apparently made no progress on the living specimens, the latter were then reinfected, but without result.

In no instance was it possible to establish *Bulgaria* on the untreated bark, although in one or two cases it maintained itself for a short time on the dead tissue at the point of infection. It is obvious that the living tissues of these specimens cannot long retain their vitality, and it would no doubt be possible to get *Bulgaria* to grow successfully after a short time, if it were not for various saprophytic moulds, and particularly a dense white mycelium, possibly of one of the Polyporaceae, which appeared on all the specimens and against which *Bulgaria* could make no headway. The results obtained from the foregoing experiments and those on the living trees indicate that whilst the fungus can establish itself readily on dead bark and on the bark of old trees, it fails completely when the bark is young and actively living.

When the fact is borne in mind that infections on young, healthy trees failed completely, though made with actively growing mycelium of the fungus, it may be concluded that there is little danger of the fungus establishing itself by chance infection of spores on young, vigorous maiden trees. The success of the inoculations on the pollard can probably be ascribed to the impaired vitality of these trees, and the consequent lowering of the power of the living tissues to resist attack. The fungus established on a dead area of bark can thus invade the neighbouring living tissues, it develops rapidly in the inner bark and attacks the cambium and the superficial layers of the wood. It may be as well to emphasise the fact that on these beeches at any rate *Bulgaria* does very little injury to the wood, but is responsible for the death and destruction of the bark.

DISSEMINATION OF THE DISEASE.

The familiar black apothecia of the fungus appear in early autumn (Fig. 5). They eject their spores in such abundance that the surrounding bark is covered by a black sooty deposit. The investigations of Tulasne(1) and Brefeld(2) have shown that the spores germinate readily, giving rise to secondary conidia or to mycelia directly according to the conditions of germination. The ascospores thus serve as a ready means for the dissemination of the fungus but by no means the only one. If they establish the mycelium on an exposed wound it is able in the enfeebled trees to extend itself to the living tissues. The principal development of the fungus takes place in the spring and early summer, as is evidenced by the active gumming that goes on at that time. When the bark has been completely permeated by the fungus the latter collects between the outer bark and the thin covering layer of cork, and forms shallow stromata on which are later formed the apothecia. Before these appear however, other fructifications are developed on the stroma in the form of numerous pycnidia. These are borne in irregular fructifications which form close beneath the lenticels and usually split the cork at those points. These prominences show in surface view the numerous irregular openings of the pycnidia, from which emerge rounded masses, or fine tendrils of black paste, which make their appearance on the surface of the bark, hardening on exposure to the air but readily dispersing when moistened with water (Figs. 4 and 5).

This paste consists entirely of the pycnoconidia (stylospores) described by Tulasne(1). They bear, both in size and form, a strong resemblance to the ascospores and behave in a precisely similar way on germination. In all the material examined at the right season these pycnidial fructifications were abundant. Their regular occurrence and relative importance appear to have been generally overlooked by later writers although Tulasne refers to them as occurring not infrequently. Fuckel (3) described them and identified them erroneously with *Tremella foliacea*, Pers. (*Ulocolla*, Brefeld), with which they have no connection. Fuckel had apparently never found them in conjunction with the apothecia and says "Die Combination beider mag immerhin als gewagt erscheinen; die entfernte Aehnlichkeit aber der Conidien mit den Schlauchsporen und die Analogie mit *Coryne*-Arten, verliehen derselben doch grosse Wahrscheinlichkeit."

The pycnoconidia are produced during the summer months, the apothecia in the early autumn and they can frequently be found together on the same stroma (Fig. 5). Biffen (6) observed the formation of the pycnidia in his cultures of *Bulgaria* on oak wood and they have appeared in all our cultures both on the bark and on plum agar.

OTHER RECORDS OF PARASITISM OF BULGARIA.

The suggestion that *Bulgaria* should be classed as a facultative parasite was first put forward by Ludwig (4) who described in 1887 a fatal attack on a fine specimen of *Quercus rubra*. A similar instance is recorded by Hennings (5) on the same species of *Quercus*, and this author is inclined to regard the fungus as a dangerous parasite.

Biffen (6), who studied the effect of the hyphae on oak wood, found that the action was too slight to warrant the supposition that the fungus is capable of causing a really serious tree-disease such as Ludwig (4) assumed. A reference to the latter's account however, shows that he attributes the death of the oak to the destruction of the bark by *Bulgaria*, and not to its effect on the wood. The results of the present investigation clearly indicate that in the beech also, the fungus is primarily a bark-parasite.

So far as the authors are aware, no account has hitherto been published of an attack on the beech, apart from a statement by Massee (7) that he has seen it on living beech, and no infection experiments have been recorded. It is noteworthy that at Burnham Beeches the pollard oaks have so far been quite free from attack.

The investigation has been confined to the pollard trees at Burnham Beeches, but the Ranger, who has examined beech plantations in various parts of the country, has found the disease on mature maiden trees in several areas in Buckinghamshire, at Tring in Hertfordshire, Walton-on-Hill in Surrey, and in the Goring district of Oxfordshire. It is

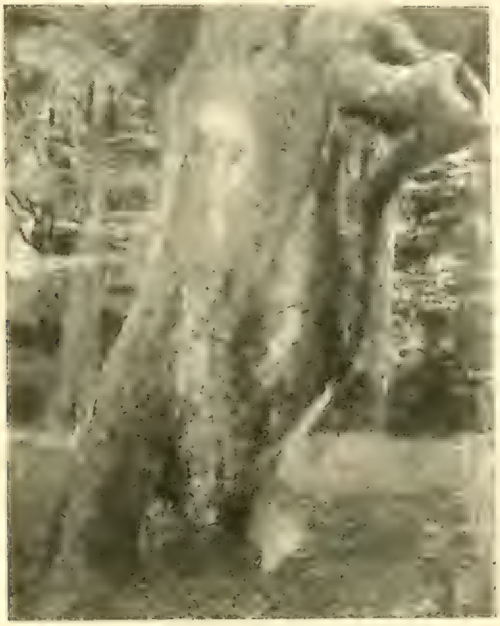

Fig. 1. Diseased pollard beech showing gumming.

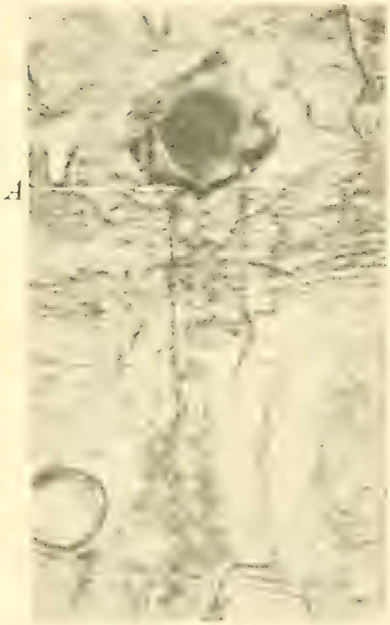

Fig. 2. Graft made in September 1915. Photographed in July 1916 to show the gum exuding from the lower edge of the graft at *A*. $\times \frac{1}{5}$.

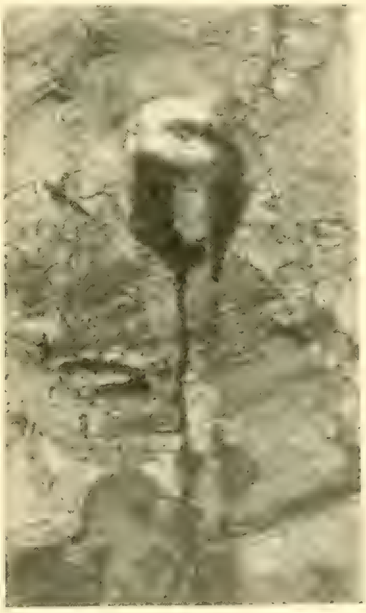

Fig. 3. Bark of pollard infected with living mycelium, July 1916. Photographed eight weeks later when actively gumming. $\times \frac{1}{5}$.

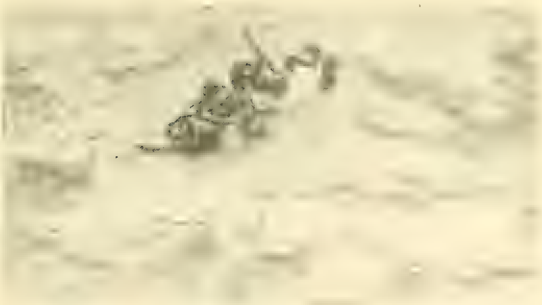

Fig. 4. Masses of pycnospores exuded through cracks in the bark from the pycnidia on the stroma beneath. $\times \frac{3}{4}$.

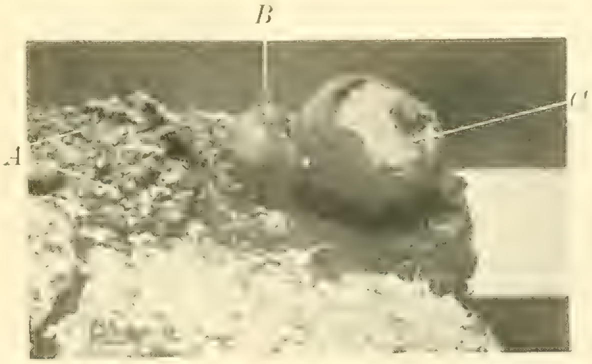

Fig. 5. Stroma exposed by the removal of the superficial cork showing masses of pycnospores at *A*, young apothecium *B*, and mature apothecium with hymenium exposed *C*. $\times \frac{3}{4}$.

obvious therefore, that the peculiar circumstance of the pollard trees is not alone responsible for their susceptibility, and it must be concluded that *Bulgaria* may prove a dangerous parasite to old beeches, more especially when from various causes their vitality may become impaired.

Up to the present the actual source and nature of the "gum" has not been determined. Preventive and remedial measures are under consideration.

SUMMARY.

A gumming disease of pollard beeches is described which is associated with the presence of *Bulgaria polymorpha*, Wett. on the trees.

A mycelium isolated from the diseased bark has been cultivated and has produced the fructifications of *Bulgaria*.

A pollard has been infected with the disease by grafting in a piece of diseased bark, and also by introducing the mycelium of *Bulgaria*.

Repeated infections of young, vigorous trees with the mycelium failed to produce the disease.

It is concluded that *Bulgaria* is a dangerous facultative parasite on old beeches, but that young healthy trees are able to resist infection.

We take this opportunity to record our thanks to M. C. Duchesne, Esq., the Ranger of Burnham Beeches, for the facilities he has readily afforded us and for the information he has placed at our disposal.

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THE LIFE HISTORY AND ECONOMY OF THE CHEESE MITES.

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The work on Cheese Mites, of which this paper gives a preliminary report, was undertaken in the Zoology Department of University College, Reading, at the suggestion of Dr R. Stenhouse Williams, of the Dairy Research Institute, and in collaboration with Mr A. Todd, Manager of the British Dairy Institute, University College, Reading.

The losses due to the depredations of cheese mites are very severe. According to statistics obtained by Dr Williams, about 100,000 Stiltons (the cheeses most affected) are made annually in this country. These cheeses weigh on the average when ripe about 14 lbs., and before the war sold at the rate of 1*s.* per lb. Estimating the average loss due to cheese mites at $2\frac{1}{2}$ % of the whole cheese (a not very excessive estimate) and the labour involved in attending to the cheeses at 4*d.* per week for each 100 cheeses for a period of 26 weeks, we obtain the following figures:

Value of 100,000 cheeses each weighing 14 lbs. at 1*s.* per lb.	£70,000
Loss due to cheese mites $2\frac{1}{2}$ %	£1,750
Labour 4*d.* per week for each 100 cheeses for 26 weeks (approx.)	£433
Total loss	£2,183

With a view to minimising and if possible preventing this loss the following work was done, aided by a research grant from the Board of Agriculture and Fisheries.

Systematic Position.

The nearest relatives of the Mites are the Spiders and Ticks. In these forms the body is incompletely divided into two, the fused head and thorax and the abdomen. There are four pairs of legs in the adult and two pairs of mouth parts, which are adapted for biting, piercing or sucking.

Many mites are parasitic, for example, the Itch mites. Others, like the cheese mites, feed on food substances, while a few are carnivorous and beneficial. As a group the Mites are much simpler in organisation than the spiders and though not very numerous in species, they cause an immense amount of damage, owing to their short life cycle, their rapid propagation, their powers of resistance and their means of distribution.

SPECIES.

Four species attack cheese. All of these are to be found on old Cheddars and three species on Stiltons and Wensleydales. It must be remembered, however, that although unpressed, ungreased cheeses suffer most damage, old cheeses of any kind are liable to attack. Further, these so-called cheese mites do not confine their depredations to cheese, but will thrive equally well on flour, stored grain, dried fruits and drugs, hay, etc., provided these are allowed to get damp. The four species of Cheese Mite, which all belong to the same family of Mites, are:

(1)	*Carpoglyphus anonymus*[1]	The Cheddar Mite.
(2)	*Tyroglyphus siro*	Stilton and Cheddar Mites.
(3)	*Tyroglyphus longior*	,, ,, ,,
(4)	*Aleurobius farinae*	,, ,, ,,

Carpoglyphus is readily distinguished from the other three species by its greater opacity. It is of a deep cream colour when found on cheese. *Tyroglyphus siro* is a somewhat sluggish species with heavy body, short legs and long hairs. *Tyroglyphus longior* closely resembles *Tyroglyphus siro*, but it is less heavily built and is exceedingly active. Its hairs are very long and its legs pinkish. *Aleurobius farinae*, the Flour Mite, has deep reddish brown legs and short hairs. The first pair of legs in the male are very stout and spurred at the base.

LIFE HISTORY.

The life history, which is similar in all the species, consists of four stages, the egg, larva, nymph and adult male or female. From egg to adult stage occupies about four or five weeks. In working out the life history the method suggested by Michael was used[2]. Glass cells were made by fixing a glass ring about one-eighth of an inch in height to a slide. The adult male and female were then placed in the cell along with a small piece of cheese, the base of the cell having been previously covered with a piece of blotting paper, which was kept moist. The upper rim of the glass circle was smeared with vaseline and a small strip of glass placed on the top as a lid to prevent the mites escaping. The cells were examined every day under the microscope and records of the duration of the various stages were kept. When about three eggs had been laid the male and female were removed but the eggs left. The exact date when the egg was laid was therefore known and the young stages became used to living in the cell. It was much more difficult to keep the mites alive, if the cells were started with the larva or the nymph stage.

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[1] The name *Carpoglyphus* means the fruit-cutter, because this species frequently attacks dried fruits. *Tyroglyphus* means cheese-cutter, *Aleurobius farinae* the living organism found in flour.

[2] *British Tyroglyphidae*, I. p. 135.

The eggs are white oval bodies, so small as to be only just visible to the naked eye. They hatch in about 10—12 days after being laid. On hatching, the young mite is known as a *larva*. It is colourless and of a glassy appearance, and has three pairs of legs only. The larva feeds actively for about a week, then becomes quiescent and casts its skin, emerging as the *first nymph*. The first nymph has four pairs of legs and is somewhat larger than the larva. It moults again and becomes the *second nymph*, larger and more highly chitinised than the first nymph. After its third moult, the mite emerges as an adult male or female, the sexual organs not being functional until the final stage is reached.

In *Tyroglyphus longior*, however, there is an additional stage after the first nymph stage, which is specially adapted for distributing the species. This stage is known as the Hypopus stage and occurs under favourable conditions, that is, when the mites are allowed to breed unchecked. The Hypopus is like a minute tortoise. It is extremely small, pinkish in colour, and has a hard, shelly back of chitin. The legs are short, the mouth parts rudimentary, and there is no evidence that it feeds. On its ventral side it has a sucker plate by means of which it attaches itself to other mites, to flies and moths which alight on the cheeses, or even to the skin and clothes of human beings. It is thus carried about until it finds a suitable place, when it drops off, moults to become a second nymph, and commences feeding.

PRACTICAL CONSIDERATIONS.

The following questions present themselves for solution.

(1) How do new dairies become infected with mites?

(2) How do new cheeses become infected in a cheese room previously attacked?

The second question may be more conveniently dealt with first and its solution involves to a large extent the answer to the first question. Stiltons are usually made from April to September, and are then cleared out of the dairies by December. From December till the end of April, that is to say, till the next Stilton season, the Stilton room is usually empty or is used for other cheeses which are not attacked by mites unless very old. From such a cheese room, which had been used since Christmas only for cheeses that are not usually attacked, scrapings from corners, window ledges and shelves were taken in June. In each case, amongst a mass of dust and dead bodies of mites, a few live mites were found. The new Stiltons were placed on the shelves at the end of June and in a fortnight's time showed numbers of mites on the coat. The mites that attacked the new Stiltons, therefore, were already present in the cheese room. The ordinary cleansing methods had failed to kill them, yet the greatest care is taken in this dairy to keep the place thoroughly clean. Eggs were never seen in the scrapings; all the individuals were adults, and it appears probable that the interval between the Stilton periods is tided over by adults. Now if these few adults are the source of mite attack on the new Stiltons, how do they spread from cheese to cheese and from shelf to shelf? It is obvious that on emerging from their retreats they will crawl to the nearest cheeses, but this does not entirely explain how they pass from one shelf to another. Two experiments were carried out in order to ascertain this. In both these experiments the crawling of the mites to the cheese was prevented by a band of grease in the one case and by a water bath in the other.

Experiment 1. A trestle stool, which had never been used in the cheese room, was thoroughly scrubbed and placed in the centre of the Stilton room. The legs were thickly smeared with vaseline about six inches from the floor. Any mites, therefore, that attempted to crawl up from the floor would be caught by the grease band. A sheet of plate glass was placed on the trestle and on it four new Stiltons. These cheeses were turned each day by the same student, who did not touch any of the mite attacked cheeses, so that it was improbable that she could carry mites to these four cheeses. Since the mites could not crawl on to the cheeses, and these were nevertheless attacked about two weeks later than the other Stiltons in the room, there were three possibilities:

(1) That the mites could be carried by flies, which were observed crawling over the cheeses.

(2) That the mites, being so small, could be blown by a draught across the small space between shelves and trestle.

(3) That the person who turned the cheeses, in spite of the care taken, may have carried the mites.

A fly paper was hung up in the room and the flies caught on it were examined under the microscope. Mites in small numbers were found attached to their legs, so that there seems to be no doubt that mites can be carried in this way. In fact, the Hypopus stage (see life history above) is specially adapted for conveyance by this means. If the mites can be carried short distances by flies, there is every possibility that new cheese rooms become infested by mites carried by flies, moths and other insects which have previously visited places where these small creatures abound.

Experiment 2. The trestle in this case was not grease banded, but on it was placed a large bath containing water to a depth of about two inches. It had been previously ascertained that mites could not traverse a piece of water, so that any mites that crawled up the legs of the trestle and over the edge of the bath would fail to reach the cheeses, which were placed on boards elevated above the water. These cheeses were attacked by mites at about the same time as those in Experiment 1, that is to say, about two weeks later than those that were put on the shelves, and presumably from the same causes, for moths and flies were seen on these cheeses also.

Of the three possibilities mentioned above, therefore, the first becomes a fact, viz., that flies and moths can carry the mites. No experiment has yet been made to show whether the mites can be blown through the air, though it is highly probable that this is the case, at any rate for short distances. The possibility of the person who turned the cheeses conveying mites must not be overlooked, though every care was taken to prevent it. Anyone who has turned mite-eaten cheeses, however, will realise that human beings can carry mites from one place to another, and will have experienced the tingling and itching sensation due to the presence of the mites on the skin. Although mites have no eyes[1], they can distinguish between light and darkness, and of the two they prefer darkness. If the breeding cells mentioned above were kept in the light, the mites hid under the blotting paper and it was often very difficult to find them. By keeping the cells in the dark, however, the mites appeared to thrive better and were more easily found when the cells were examined from day to day. It follows from this that mite attack is worse in a dark cheese room than in a light one, and the practice of having cheese rooms partly or entirely under-ground is favourable to the mites, although necessary in order to maintain an even temperature.

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[1] *Carpoglyphus* has "eye-like organs," but these have no pigment and it is doubtful if this mite can see.

Their fondness for darkness, however, is excelled by their love of cracks, crevices and corners. They creep into cracks in the cheese boards and shelves, and soap and boiling water will *not* kill them. It is, in fact, extremely difficult to kill the adult mite and almost impossible to kill the egg. These mites have no breathing organs, but breathe through the thin cuticle, so that it is far more difficult to kill them by suffocation or fumigation than it would be if they possessed breathing tubes like those of insects. The methods employed in the dairies for keeping them in check are therefore often only waste of good material. Some cheese makers, for example, dip the cheese in formalin, believing that the formalin will kill the mites. Mites have been kept immersed in 5 % formalin *for over a week* and at the end of that time, though some had died, many were still active! The formalin washes off the surface mites, but kills none of them. A very large number of substances were experimented with, but only two were found which killed the mites within a short time. These were Carbolic acid and Carbon bi-sulphide. Carbolic acid, being poisonous, cannot be used on the cheeses themselves, but it might be used for scrubbing the shelves, and especially the corners. A 5 % solution killed the mites in two minutes; increasing the strength did not cause their death any sooner than this. Four 10 lb. Stiltons were removed to an unused room, freed from mites and kept free by the use of Carbon bi-sulphide. This substance is a heavy, yellow and evil-smelling liquid which vaporises very readily and which leaves behind neither smell nor taste. It is used on flour, grain and many other food stuffs and destroys all forms of animal life. It is not harmful when breathed in small quantities by human beings, but is highly inflammable and should not be brought near a light. The vapour of the bi-sulphide kills the mites almost instantaneously, but although it is a heavy gas, the vapour does not work underneath the cheeses, neither does it kill the eggs. The bi-sulphide was used in several ways until the most satisfactory was found. (1) The cheese was covered with a bell jar and a shallow vessel containing the bi-sulphide was stood on an inverted gas jar placed inside the bell jar. The bi-sulphide was then left to evaporate. The reason for elevating the fumigant is that the vapour is heavy and therefore sinks. The majority of the mites were killed, but some still survived at the base of the cheese. (2) The cheese was sprayed with the bi-sulphide by means of an ordinary garden spray. It was then inverted and the base treated. This method is, however, wasteful. (3) The cheese was painted all over the surface with the bi-sulphide by means of a large paint brush. This method was found to be the most effective, though it would be difficult of application on a large scale and the cost might be prohibitive[1].

It was necessary to treat the cheeses three times, once to kill the adults, a second, at an interval long enough to allow for the hatching of the eggs, to kill the larvae, and a third after a similar interval to make sure that all were killed. Thus the four cheeses received their first treatment on September 11th, 1916, the second twelve days later, and the third after the same interval. No mites were afterwards observed, the cheeses ripened satisfactorily and were kept free from mites from October, 1916, to February, 1917, when they were returned to the dairy and sold.

Further experiments with Carbon bi-sulphide will be carried out on a larger scale during the present year. I do not think, however, that it would be easy to free large numbers of Stiltons from mites by any fumigant when once they have been attacked. The mites are so small and breed so rapidly that it is extremely difficult to exterminate them. The hope seems to lie rather in preventive methods, that is, in a thorough cleansing of the dairy in the interval between the clearing out of the ripe Stiltons and the making of the new ones, and an attempt to do this will be made in the cheese room at University College, Reading.

The following recommendations arise naturally from what has been said above:

(1) All the windows should be netted to prevent the entrance of flies and moths, which carry mites. If doors are left open, they should have a netted inner door for the same purpose. This precaution would also eliminate "skippers" from the cheeses, by preventing the ingress of cheese flies.

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[1] The price of Carbon bi-sulphide is at present 11*d.* per lb. About 5—8 ozs. were used for the four cheeses in question at each fumigation and there were three such fumigations, so that the total cost was about 1*s.* 6*d.* for the four cheeses. The cheeses were subsequently turned but not brushed as there was no dust on them. The cost of brushing was therefore saved.

(2) There should be a very thorough cleansing of the dairy between one Stilton season and the next in order to kill those mites that persist and are waiting to attack the next set of Stiltons. Corners, window ledges and crevices of any kind are their favourite hiding places, and the whole of the ceiling, walls, floors, shelves and their supports should be thoroughly cleansed, and all woodwork treated with 5 % Carbolic solution. If the walls are not tiled or made of glazed brick, they should be lime-washed every year. Limewash does not kill mites, but the movements of the brush would dislodge them or perhaps crush them.

(3) It is advisable to have movable shelves of short lengths. Ideally the shelves would be made of glass, as then only could one be sure that there were no mites on them. The supports are better made of iron than of wood, because, with scrubbing, the cracks in the wood increase in number and depth and so harbour the mites. For the same reason, floors should be made of concrete, with gutters for drainage. If the Stilton room is not in use between the Stilton seasons, the shelves should be removed, treated with Carbolic and then kept in daylight and allowed to dry.

(4) When Stiltons are attacked by mites, the damage is lessened very considerably by brushing the cheeses daily and removing the mite dust.

INVESTIGATION OF BULB ROT OF NARCISSUS[1].

PART I. THE NATURE OF THE DISEASE.

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(With Five Text-figures.)

Introduction.

The date of the first appearance of the disease in this country is somewhat doubtful. Mr J. W. Barr, of Messrs Barr and Sons, states that he first observed it about twelve years ago in some bulbs of *Narcissus Horsfieldii* imported from Holland.

Massee (9) found *Fusarium bulbigenum* (Cooke and Massee) in Narcissus plants suffering from bulb rot and ascribed the disease to this cause. As, however, no infection experiments were carried out, and as there seems some evidence that *Fusarium bulbigenum* may exist in healthy bulbs, it is clear that the nature of the disease was not settled by Massee's observations. The absence of definite knowledge as to its cause and the increasing ravages of the disease obviously made an investigation very desirable.

Diseased bulbs were obtained in April, 1915, and a preliminary examination showed them to be infested with various animal pests, chief among which were *Rhizoglyphus echinopus*, *Eumerus strigatus*, *Merodon equestris*, and *Tylenchus devastatrix*; certain scales were also found to contain *Fusarium bulbigenum* and bacteria. It was necessary, therefore, to determine which, if any, of the above was the primary cause of the bulb rot.

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[1] This investigation was undertaken jointly by the Imperial College of Science and Technology and the Royal Horticultural Society.

Infection Experiments.

A series of experiments was begun in September, 1915, on bulbs grown in cold frames at the Imperial College of Science and Technology, and in prepared beds at Chelsea Physic Gardens. It was found, however, that more trustworthy results would be obtained if the bulbs could be grown under better conditions, such as those obtaining in the larger nurseries. For this purpose, Messrs Barr and Sons were good enough to provide facilities, and since March, 1916, experiments and observations have been carried out in their fields and drying sheds at Taplow.

Infection with Bacteria.

Infection experiments were carried out with seven strains of bacteria which had been isolated from diseased bulbs and grown on either Narcissus or potato-mush agar. Healthy bulbs were planted in September, 1915, and were infected with pure cultures of the several strains in the following month. A piece of the bulb was cut out with a sharp sterilised scalpel and a portion of agar with the bacteria was placed at the bottom of the pit, after which the piece of bulb was replaced. Healthy cut and uncut bulbs were planted as controls. When the plants were examined in the following spring and autumn, they were all found to be quite healthy.

The experiments were repeated during May and June, 1916, but again with negative results.

It was, therefore, concluded that the bacteria which had been isolated from the scales of diseased bulbs were not the cause of the disease.

Infection with Fusarium bulbigenum.

This fungus was isolated from diseased bulbs and grown on sterilised potato-mush agar, it grew vigorously and produced conidia of the Monosporium and Diplocladium types. A series of experiments was then made; sixty bulbs of the varieties *Narcissus Leedsii, Narcissus bicolor* Barri conspicua, *Narcissus incomparabilis* Cynosure, were cut and infected with portions of agar bearing Fusarium. The Fusarium was used in three stages: (1) rapidly growing non-fruiting mycelium from the edge of a culture; (2) mycelium bearing conidia of the *Monosporium* type, and (3) mycelium with conidia of the *Diplocladium* type.

In every case the bulbs remained perfectly healthy, though the fungus was often found growing between the dead outer scales of the bulb. There was no indication that the fungus had any action on healthy bulbs. The examination of a large number of bulbs leads to the conclusion that *Fusarium bulbigenum* is very often present on the surface of the dead and dying outer scales of healthy bulbs. It is especially abundant in bulbs which have been injured, but even on rotting scales it seldom penetrates far into the tissues. It is evident, therefore, that the presence of *Fusarium bulbigenum* is not sufficient to account for Narcissus rot.

Infection with Black mycelium.

A very dark coloured, almost black mycelium was isolated from diseased bulbs and a series of infection experiments was carried out. The infected bulbs remained perfectly healthy. It was, therefore, obvious that this mycelium did not cause bulb rot, and no attempt was made to obtain conidia or to determine the fungus.

Eumerus strigatus *and* Merodon equestris.

It has been shown by Fryer (4) that the larvae of these two insects do much harm to Narcissus plants, causing a weak, distorted growth, and the loss of a large number of plants. The damage caused by them is, however, quite distinct from the symptoms known as bulb rot.

Infection with Rhizoglyphus echinopus.

These bulb mites are very common on unhealthy bulbs, and are consequently easily obtained for experimental work. The mites were lifted off the diseased bulb with a sable brush and were gently transferred to a healthy bulb, some being put between two injured scales and some between two perfect scales. The bulbs were not planted until the mites were seen to move and were therefore presumably uninjured by the manipulation. These insects undoubtedly do a great deal of harm; they puncture the scales, and gradually cause their destruction, thus weakening the bulb; but in no case was bulb rot obtained by the use of *Rhizoglyphus echinopus*, and it seems, therefore, improbable that the mite causes the disease either by eating the bulb or by carrying bacteria into its tissues.

Infection with Tylenchus devastatrix *Kuhn.*

During the course of this investigation more than one hundred diseased bulbs have been dissected and in all of them eelworms or their eggs have been found. Small portions of tissue containing live worms were consequently easily obtained and were placed on the cut surface of the scales of healthy bulbs. Fifty bulbs infected in this way were planted in a box of sterilised soil in October and were kept in a cold frame till the following spring. By the middle of February they all showed the characteristic symptoms of the disease under investigation, namely, precocious growth, an abnormally well-developed root system, blotches on the leaves and, above all, discoloured and rotting bulb scales. No Fusarium was observed. Another set of bulbs treated in a similar way, but planted in unsterilised soil, also developed bulb rot. Healthy bulbs, some of which were cut and the rest uninjured, were planted in both sterilised and unsterilised soil as a control; *all* these bulbs remained healthy and showed no symptoms of disease.

When these results are considered in relation to the invariable presence of eelworm in naturally diseased bulbs and to the fact that organisms, such as Fusarium and bacteria, which may be found associated with these nematodes, are unable to cause bulb rot, it becomes clear that the eelworm, *Tylenchus devastatrix*, is the sole cause of the disease.

COURSE OF DISEASE.

Healthy bulbs may become infected at any time of the year provided the ground is sufficiently warm for the eelworm to be active. When the tissue in which eelworms are living becomes decayed they forsake it and pass into the ground. In a short time they infect another bulb, entering it either by the bases of the old leaves, which, as is the case with Monocotyledons, are unprotected by a callus, or by young leaves which have been injured and are just pushing up through the soil (Fig. 1). The first noticeable sign of disease in the young leaves is the appearance of pale green areas; these areas become yellow, and, then spreading downwards, produce discoloured "stripes" on the bulb scales. If such an affected portion of leaf is examined, eelworms will be found in the tissue; they lie parallel to the course of the vascular bundles and pass downwards between the cells (Fig. 2). In a few weeks after infection the tissue will contain a large number of eelworms and probably also numerous eggs. It is sometimes difficult to be certain of the presence or absence of eelworms and especially of their eggs, but both can be demonstrated easily by the following method. The material to be examined is fixed in 25 % acetic-alcohol and hand-sections are stained in Ziehl's carbol fuchsin for about an hour, the stain

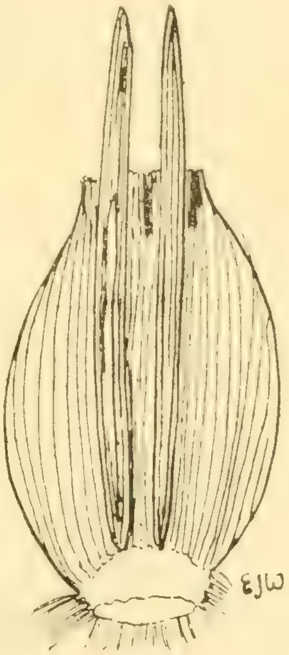

Fig. 1. Infection at crown on bases of old leaves and on young leaves.

is washed out in alcohol till the plant tissue is almost colourless. By this method the eggs and worms are stained a bright red and are seen as easily in thick as in thin sections.

The infected leaf slowly dies from the tip downwards, and the eelworms, both mature animals and larvae, migrate into the lower portion of the leaf within the bulb. The dead upper portion of the leaf falls on to the ground and if the weather is sufficiently warm the eggs hatch and young larvae are soon liberated in the soil through which they can pass to a healthy bulb. Cold weather makes the eelworms sluggish, or dormant, or even kills them, and consequently checks infection.

Having once entered the bulb, either through the old leaf bases or the young foliage, the eelworms pass slowly downwards to the "plate" leaving the scales discoloured as a whole or in part. If such a diseased bulb is cut across transversely the discoloured scale is seen as a brown ring or part of a ring (Fig. 3). If cut longitudinally the diseased scales appear as clearly marked brown stripes (Fig. 4). It is generally the case that bulbs which have a discoloured scale have also an unusually luxuriant root system.

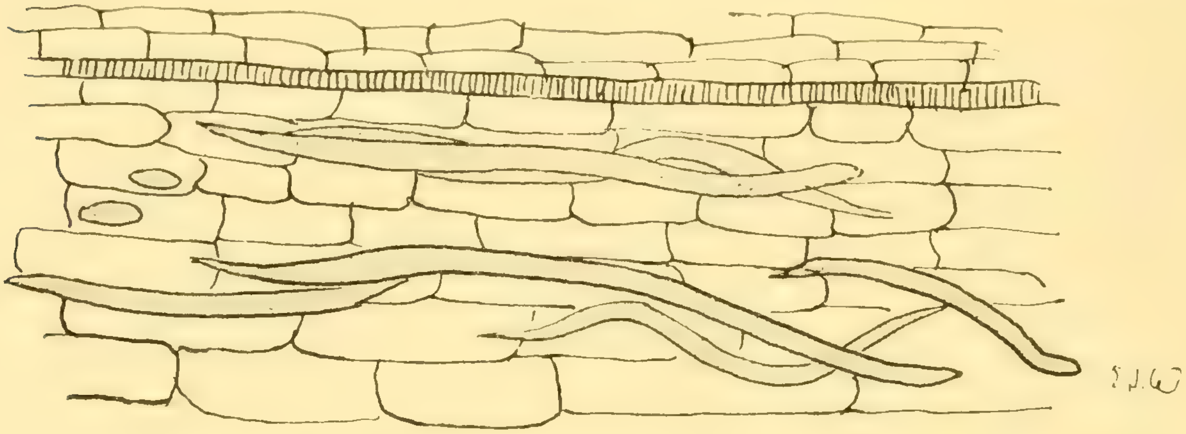

Fig. 2. Eelworms in tissue of bulb scale. ×300.

When the eelworms reach the plate they leave the scale down which they have travelled and enter another scale up which they make their way. Thus they are able to reach the green blades again. Blades infected in this way look quite healthy till they suddenly fall over and die. Such a stage is reached in about the month of June when whole masses of leaves may fall within a week. It is obvious that this falling of the foliage is not due to any new outbreak but merely marks a stage in a disease which has been present in the bulbs for many weeks.

As the season advances the diseased bulbs contain an increasing number of eelworms, eggs, and larvae. When such bulbs are removed to the drying sheds many of the mature worms forsake the scales, no doubt owing to the gradually increasing dryness, and they may be found in bunches among the roots. In this position they are subjected to rapid desiccation and they soon become dormant and fall off, often on to healthy bulbs. If such worms become moistened they revive in a very short time and speedily infect the material around them. Again, if the sheds are warm, the eggs, which have been deposited in the scales, hatch and the larvae attack the tissue in which they are lying. Dry, cool conditions check the spreading of the disease and prevent the occurrence of fresh infection; unfortunately such conditions are difficult to obtain in practice.

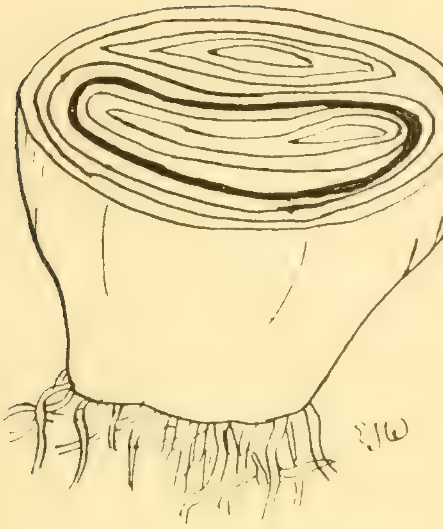

Fig. 3. Diseased bulb showing ring of brown tissue.

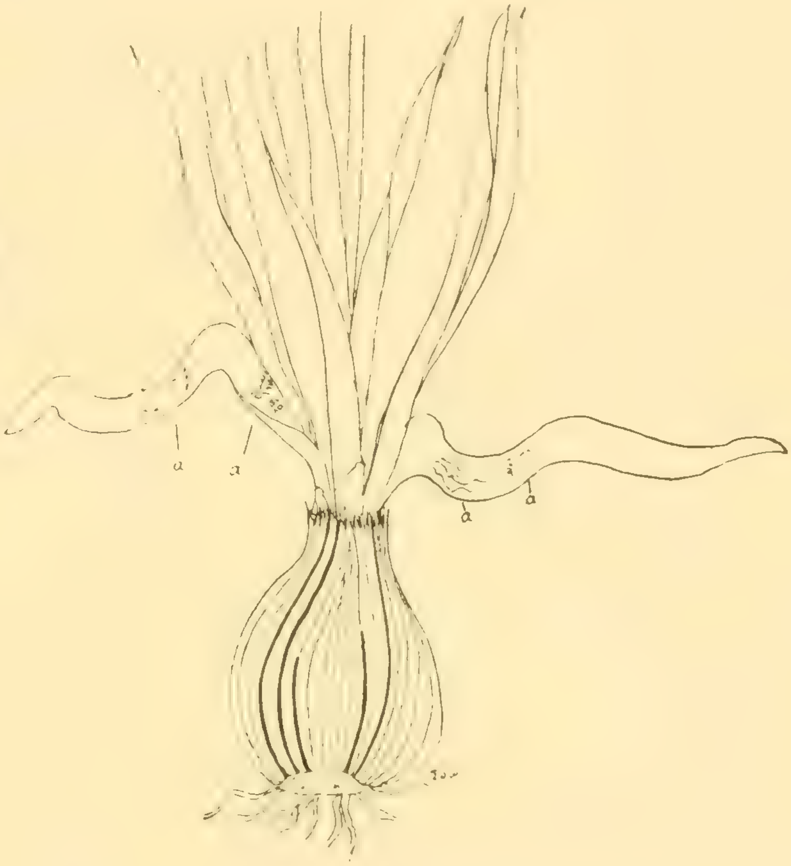

Fig. 4. Diagrammatic drawing of bulb which has been cut in half longitudinally. Second year of attack. Infection spreading up from plate. a = crinkly leaves growing at right angles to bulb.

When diseased bulbs are planted in the autumn a certain proportion of them die and liberate eelworms which infect their neighbours. Those which survive start growing earlier than healthy bulbs (Fig. 5), and in the spring often produce one or more curved leaves showing crinkled areas (Fig. 4). Owing to the large number of eelworms in such bulbs it usually happens that the disease spreads quickly, thus separating the scales from the plate; such plates bearing only roots are often found in beds in which the bulbs are very badly attacked. It seems probable that in these cases the disease has started in the previous year.

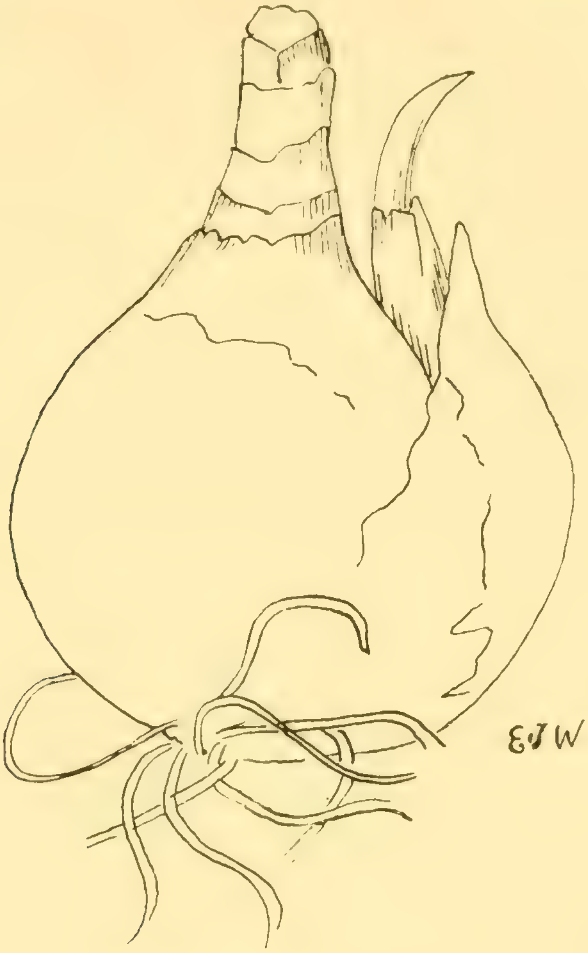

Fig. 5. Early growth of diseased bulb. August.

GENERAL CONSIDERATIONS.

Eelworm is well known in Europe because of the destruction it causes to various cultivated crops, especially to rye, hyacinth and onion.

Kuhn (5, 6) in 1867 and 1868 described a disease in rye and showed that it was due to the action of an eelworm, *Anguillula devastatrix.*

In 1881 Prillieux (10) investigated the "ring" disease of hyacinths and attributed it to an eelworm, *Tylenchus hyacinthi.* Two years later the onion disease was shown by Beyerinck (1) to be due to *Tylenchus Allii.*

Owing to the terrible destruction of hyacinths in Holland the "ring disease," as it is called, has been thoroughly studied in that country, more especially by de Mann (7) and by Ritzema Bos (2,3). The latter believes that the slight differences which exist between the eelworms parasitic on rye, hyacinth, onion and numerous other plants are not of specific value but are due to environment. He considers that the eelworm present in these plants should be called *Tylenchus devastatrix*, Kuhn, and he publishes a diagnosis of the species with a detailed description and numerous figures (III. pp. 185, 220). As the characteristics of the eelworm found in Narcissus bulbs in England agree exactly with the diagnosis of *Tylenchus devastatrix* as given by Ritzema Bos, there seems no doubt of the correctness of the identification here put forward.

According to Ritzema Bos (III. pp. 232–234), *Tylenchus devastatrix* attacks a variety of cultivated and wild plants, and though it is capable of passing from one to the other it does not do so easily. He concludes that there are physiological varieties of the species and says: "Il paraîtrait donc qu'on peut admettre comme règle, que le *Tylenchus devastatrix* se fixe dans les plantes dans lesquelles les ancêtres ont vécu depuis plusieurs générations, de préférence à d'autres espèces de plantes; et que, toutes choses égales d'ailleurs, il préfère ordinairement la plante ayant une parenté étroite avec celle dans laquelle vivaient les générations précédentes, à celle qui en est plus éloignée dans le système.

"J'estime qu'on pourra trouver dans ce qui précède la clef de bien des choses, inexpliquées jusqu'ici relativement à l'apparition et à la disparition des maladies vermiculaires dans nos cultures.

"Il résulte d'ailleurs de ce qui a été traité jusqu'ici dans ce chapitre, que, si au point de vue *morphologique* il faut considérer comme une espèce unique les *Tylenchus* des jacinthes, ceux de l'oignon, ceux du seigle, du sarrasin, du trèfle, etc., et ceux de la mousse *Hypnum cupressiforme*, il existe néanmoins des différences *physiologiques* entre les différentes *Tylenchus*, selon que leurs ancêtres ont vécu durant un grand nombre de générations, dans telle ou telle plante."

The differences between the eelworms of hyacinths and of onions indicated by Ritzema Bos suggest a comparison with the "biologic forms" described for various parasitic hosts. It is to be noted, however, that Ritzema Bos ascribes to the eelworms merely *preferences* for their original host while the biologic forms are normally confined by physiological differences to their particular host or set of hosts. The physiological differences between the onion and hyacinth "forms" of eelworm, if they exist, are obviously less definite than those which differentiate the biologic forms of the Uredineae and of the Erysiphaceae.

If the eelworm of Narcissus follows the behaviour described by Ritzema Bos for that of the hyacinth and of the onion it is clear that while the bulbs are in the ground there is very little fear that it will migrate to neighbouring weeds. However, directly the bulbs are lifted any eelworms remaining in the ground are likely to migrate to suitable weeds[1] which thus would become valuable traps. It is desirable, therefore, that before replanting the ground all weeds should be removed and burnt; weeds should never be allowed to wilt on the soil nor should they be dug in.

A list of the more common British weeds and cultivated plants which have been described as affording shelter to *Tylenchus devastatrix* is given here. It is compiled from papers of Ritzema Bos(2,3); it has no claim to completeness.

Medicago sativa
Trifolium pratense
Polygonum fagopyrum
,, convolvulus
,, persicaria
,, lapathifolium
Bellis perennis
Ranunculus acris
Geranium molle
Sonchus oleraceus
Myosotis stricta
Plantago lanceolata
Poa annua
Holcus lanatus
Brassica rapa
Anthoxanthum odoratum
Centaurea jacea
,, cyanus
Spergula arvensis
Allium cepa
,, proliferum
,, vineale
,, schoenoprasum
Hyacinthus romanus
,, orientalis
,, precox
Tulipa gesneriana
Lilium candidum
Fritillaria imperialis
Galtonia candicans
Scilla sibirica
,, campanulata
,, cernua
Narcissus Tazetta
,, Pseudo-narcissus
Muscaria botryoides
,, comosum
Humulus lupulus
Phlox
Chelone glabra
Solanum tuberosum
Wheat
Rye
Oats
Vicia Faba

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[1] The question of the occurrence of migration and its extent would be well worth investigation.

Ritzema Bos found eelworms in some plants of *Narcissus Tazetta* which he had planted in soil infested with the eelworm of barley, but he states that bulb growers in Holland find that Narcissus bulbs do not suffer from bulb rot. He says (III. p. 230) "J'appris aussi par des cultivateurs de bulbes à fleurs de Haarlem, que les tulipes, les lis, la couronne impériale et les narcisses ne sont jamais atteints de la maladie causée par les anguillules (maladie annulaire)."

Thus in 1887 it is clear that the eelworm disease of Narcissus was little known in Holland though it was then very prevalent among Hyacinths.

The occurrence of eelworm disease in Narcissus is mentioned by Marcinoswski (8) in 1910 but no account is given of it and it seems reasonable to conclude that though it was recognised in Holland in 1910 it was comparatively rare.

Hewitt (4A), working in Ireland, seems to be the only other investigator who has described the occurrence of *Tylenchus devastatrix* in Narcissus bulbs. His paper is short and deals mainly with the action on the bulb and organism of various "steeps." In the light of our present knowledge it is clear that he was dealing with "bulb rot"; but his description of the diseased condition is so brief that apart from the nature of the infecting organism the nature of the disease he describes would remain uncertain.

The account given here of the cause and progress of the bulb rot of Narcissus shows that certain precautionary measures will check to some extent the ravages of the eelworm. Such measures may briefly be summarised as follows:

(1) Narcissus should not be planted in ground previously infected with *Tylenchus devastatrix*; the danger is especially great if the eelworms have been liberated from a previous crop of Narcissus.

(2) Care should be taken to plant healthy bulbs only; one diseased bulb will soon infect many others.

(3) When a bulb does not produce foliage at the proper time it should be dug up and burnt before it rots and liberates eelworms in the soil.

(4) Bulbs with "crinkly" or very curved leaves should be burnt.

(5) Dying leaves should be gathered and burnt before they can fall on the soil and so possibly infect it.

(6) Weeds growing in infected soil should be pulled up, put directly into baskets, and burnt.

SUMMARY.

The bulb rot disease, or ring disease, of Narcissus is due to the attack of an eelworm, *Tylenchus devastatrix.* These eelworms are of constant occurrence in the diseased bulbs, and the disease can be produced by infecting healthy plants with the eelworm.

A description is given of the symptoms and course of the disease as it appears in nature, and certain precautionary measures are suggested.

I have great pleasure in expressing my thanks to Mr J. W. Barr (Messrs Barr and Sons), Mr Hales (Chelsea Physic Gardens), Mr Leake (The Floral Farms, Wisbech), Mr Pearson (Messrs J. R. Pearson and Sons), and Mr J. Walker (Walker Bros.) without whose cordial cooperation and generous help the work could not have been carried out. I am also indebted to Mr J. C. Fryer for help and suggestions with regard to treatment.

I should also like to take this opportunity of thanking both Professor V. H. Blackman and Professor J. B. Farmer for their stimulating and helpful criticism.

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NOTES ON A PLAGUE OF PSOCIDS IN A FACTORY.

By R. A. HARPER GRAY, M.A., B.Sc. (Agric.), M.Sc.

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The small insects belonging to the family Psocidae cannot as a whole be regarded as injurious either to growing plants, or to plant products in their manufactured state. Their food is said to consist for the most part of minute fungi, such as moulds, and of animal or vegetable refuse[1], and they, therefore, are seldom attracted to any material of value.

From time to time, however, Psocids are recorded as being destructive to such objects as corks, books, insects in collections, etc., and in most cases it seems likely that the objects attacked had been kept in damp surroundings and were, therefore, affected with moulds or other fungi. An instance is mentioned by Theobald, for example, in which the Psocid *Atropos divinatoria* was referred to him with the complaint that it was appearing in large numbers from an old mattress, and "causing some consternation[2]."

The genera most often associated with this type of damage are *Atropos*, sometimes known as "Book Lice" (owing, doubtless, to the fact that they are frequently found in the neighbourhood of old books or papers which have not been disturbed for some time), and *Caecilius*, but it seldom seems to have been recorded that either has been responsible for serious loss from the financial point of view.

It may, therefore, be of interest to describe a case in which a stoppage of work in an important factory where straw mattresses are made was actually brought about by insects of the genus *Caecilius* (*C. pedicularius*[3]). These psocids had established themselves to such an extent that when the large double doors of part of the building, referred to below as the "loft," were opened in the morning, they could be seen flying out in thick clouds. When, further, complaints began to be made by customers about large numbers of insects appearing in bedrooms where newly purchased mattresses were being used, the manager of the factory recognised the seriousness of the outbreak, and wrote a letter to the writer, requesting advice as to how to get rid of the pest.

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[1] *Cambridge Natural History*, vol. v, p. 393.

[2] Report on Economic Zoology for the year ending September, 1910, in *The Journal of the South-Eastern Agricultural College, Wye*, No. XIX.

[3] Specimens were submitted to Dr Gahan of the British Museum of Natural History, who kindly identified them as belonging to this species.

In order to ascertain the nature of the buildings and the manner in which the straw for making the mattresses was being stored, a visit was paid to the factory, when it was found that three buildings were involved, viz.

(*a*) the loft, in which the straw was stored,
(*b*) the making-room, in which the mattresses were made,
(*c*) the store-room, where the finished mattresses were stored.

The insects were most numerous in the loft, which measured 18½ feet high, by 28 feet long, by 15 feet wide, the other rooms being slightly less. No fresh straw had been brought in after the old had been used up, so that the nature of the flooring could be easily examined. It was of concrete, and there were a few fairly wide cracks running across the whole width. In these cracks immature forms of Psocidae were observed.

The measures successfully adopted to get rid of the pest may be put briefly as follows:

(1) The ventilators in the loft were closed, and all crevices (round the doors, etc.) were covered over with paper carefully pasted on—the door through which the fumigant was admitted being dealt with immediately after being closed.

Ten pounds of rock sulphur (previously broken up in a sack by means of a mallet) were placed in an iron pot, and some hot cinders thrown on top. The pot was placed in the middle of the room, and instructions were given not to open the doors until twenty-four hours had elapsed. The other rooms received similar treatment.

(2) The loft having been thoroughly ventilated after fumigation, the walls were then carefully whitewashed (the whitewash containing some carbolic acid) and the floors of all the rooms were washed out with water and carbolic soap.

(3) It seemed probable that a few Psocids might appear in a week or two, seeing that the eggs might not be affected by the treatment, and, indeed, six days after the fumigation, a report was received stating that the insects were beginning to reappear. The writer accordingly visited

the factory and found a few Psocids mostly near the windows—in quite a sufficient number to start another plague of them. It was, therefore, decided to repeat the treatment, but to use fifteen pounds of sulphur instead of ten pounds for the second fumigation. After twenty-four hours' fumigation, the floors were again washed out with carbolic soap, and creosote was carefully poured down, along the cracks in the floor of the loft. The manager was recommended to close up these cracks with cement, after this second fumigation.

Six weeks afterwards a letter was received from the manager in which he said: "I am pleased to be able to tell you that there has not been a recurrence of the plague of flies," and a recent examination of the buildings showed that the treatment had been successful. The cracks had been closed up with cement as recommended.

With regard to the probable source of the outbreak it should be mentioned that straw coming in from one of the farms supplying the factory was dirty and in bad condition. The supply of straw from the particular farm was stopped when it was pointed out that this was most probably the source of the trouble, and the writer recommended that care should be taken to secure good clean straw in future. It seems, therefore, likely that the continued freedom from the pest now for nearly six months, is due to this precaution following upon the measures taken against the insects that had succeeded in establishing themselves in the factory.

Although the Psocids do not attack man, it is interesting to record that in the case of the above outbreak, an eruption appearing on the skin of a child sleeping in a bedroom containing a newly purchased mattress from which the insects were emerging, was not unnaturally attributed by the mother to the presence of the Psocidae.

A BACTERIAL BLIGHT OF PEAR BLOSSOMS OCCURRING IN SOUTH AFRICA.

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(With 7 Text-figures.)

During the seasons 1914—15 it was observed by fruit growers in the Stellenbosch district that a large percentage of the pear blossoms blackened and then died, and that in some varieties only a very small number of mature fruits were produced. The blackening was at first attributed to *Fusicladium*, but winter spraying seemed to have no effect on the prevalence of the trouble and specimens were therefore sent to this Laboratory for examination. The discoloured tissues were found to be swarming with innumerable bacteria; from these a pure culture was readily obtained of an organism which caused blackening in pear blossoms, artificially inoculated within a few days. The organism was re-isolated, and studied with a view to comparing it with the two organisms which are known to cause blight in fruit blossoms and which will be referred to in detail presently; one of these is the well known "Fire Blight" organism, *Bacillus amylovorus*, which occurs commonly in America, and the other a *Bacterium* recently described by Barker and Grove, as causing a blight of fruit blossoms in England. The South African organism proved to be distinct from either of these.

It is interesting to note that during some experiments carried out at the Elsenberg Agricultural College, in an orchard which has since been found to be heavily infected with the blossom blight, it was found that if the flowers were covered with paper bags before they opened almost 100 % set, as many as 32 to one truss in some cases; whereas when the flowers were not covered a large percentage fell. This was attributed to the fact that the blossoms were sheltered by the bags from high winds and sudden changes of temperature, but it seems more probable that it was due to the flowers being protected from the visits of bees and other insects which have been shown both in this case and in the case of other diseases of a similar nature to be the principal carriers of infection.

Comparative Schedule.

	Bacillus amylovorus	Barker and Grove's Organism	*Bacterium nectarophilum*
Dimensions	·9—3 μ × ·7—1 μ	2—4 μ × ·5—·8 μ	·5—3 μ × ·45—·7 μ
Flagella	Several peritrichous	Polar 3—6	Polar 1—5
Capsule	None	None	Always present
Optimum Temp.	25—30° C.	15—18° C.	25—30° C.
T. D. P.	43·7° C.	—	40° C.
Pigment	None	Some fluorescence in old cultures	Fluorescent
Agar colonies	White, circular, elevated, wet, shining, margins irregular	Whitish, circular, smooth margins	Spreading, irregular margins
Nutrient Broth	Clouding not heavy, pellicle and rim slight, moderate amount of grey deposit	Well clouded, appreciable deposit and slight rim and pellicle	Very turbid, deposit heavy, rim and pellicle present
Gelatine Stab	Slow crateriform liquefaction	Liquefaction rapid, first crateriform then stratiform	No liquefaction
Milk	Coagulated in 3—4 days, later digested to pasty condition	Slowly peptonised	Slowly peptonised
Vegetable Cylinders { Potato Carrot Turnip Beet	Good growth on all, best on beet, weakest on turnip, liquid heavily clouded	Fair on potato, feeble on carrot, none on turnip	Fair growth on all but heavy on none
Uschinsky's solution	Growth copious, not viscid	No growth	Heavy, viscid growth
Indol	Considerable quantity produced	Reaction only obtained after warming	None produced
Diastatic activity	Strong	Feeble	Feeble
Group numbers	221,232201	221,3332123	222,2332123

During September, 1916, I was able to visit the pear-growing district, and to study the disease in the orchard; it was too early for the late-flowering varieties, some of which are the most susceptible, but considerable infection was found in the Keiffers and other varieties which were then in flower. Information as to the susceptibility of the different varieties was also gleaned from various growers, all of whom mentioned the same varieties as the most liable to the disease.

Pear trees flowering in the Wellington District and in the Pretoria District show no signs of the blackening: a trouble of a somewhat similar nature has been reported from Potchefstroom, but it has not yet been ascertained whether this is identical with the blight at the Cape or not. With the exception of a case of infection reported from Wynberg, therefore, the disease is only known to occur up to the present in the Stellenbosch District and at Elsenberg. It is particularly interesting to find that there are three organisms showing a parasitism, in many respects similar, in different parts of the world; it is therefore my intention to describe the South African disease, and to compare it with the blossom blight occurring in England and with that caused by the fire blight bacillus in America.

Through the courtesy of Professor Barker and Mr Grove who supplied me with a culture of their organism I have been able to make a detailed comparison of the South African and English bacteria. My knowledge of the American blight is less complete, being gathered from the literature to which I have access, and which is by no means exhaustive; sufficient information has been gathered by this means, however, to establish the main points of difference between *Bacillus amylovorus* and the other organisms causing blossom blight in pears.

I. Fire Blight.

Bacillus amylovorus (Burr) de Toni.

The information summarised in the succeeding paragraphs has been derived from the publications listed in the "Literature cited" (numbers 4—11).

"Fire blight" was one of the first bacterial diseases of plants to be recognised as such, and consequently has been studied in considerable detail. It is very widely distributed in the United States and in Canada, and has recently been recorded (8) from several places in Italy. It causes very serious losses, amounting in California in the last fifteen years to one-third of all the full-grown orchards, and to a money loss estimated at $10,000,000 for the five years preceding the efforts for its restriction begun in 1905 by the United States Department of Agriculture (8).

In 1912 a variety of pear in Switzerland was severely injured by a bacterial invasion (7). It is thought that the disease may be similar to the pear blight in America caused by *Bacillus amylovorus*, but complete identification of the organism has not yet been found possible.

Although most common and most disastrous on the pear (*Pyrus communis*) *Bacillus amylovorus* is also found as a parasite on the apple (*Pyrus malus*), Quince (*Cydonia vulgaris*), a number of species of *Prunus* including the plum and apricot, and on numerous plants indigenous to America. Of the varieties of Pear which was attacked, the Bartlett is said to be very susceptible; other varieties are bracketed with the Bartlett as susceptible, but there seems to be considerable divergence of opinion on this point. The Keiffer, Duchess and Winter Nelis, and the oriental group in general are more resistant.

Symptoms.

Although infection most frequently takes place through the flowers, the blossom blight is not by any means the most serious phase of this disease. When the blossoms are attacked the receptacle becomes blackened first, infection taking place through the nectaries, but the infection rapidly spreads into the ovary and the flower stalk and invades the twigs. The blossoms and leaves of affected twigs become discoloured, turning light or dark brown, or sometimes red, and finally shrivel up and die. The spread of infection is frequently so rapid as to result in the complete blackening and death of all branches and spurs upon which flower clusters have been borne. The blight may continue to extend down the branch or twig, the branch being entirely killed as it progresses, and in course of time it may extend into the larger limbs. The bark of infected twigs and branches becomes blistered, and on the blistered areas there is often found a gummy exudate which is crowded with the rods of the causal organism; this exudate attracts the insects which are responsible for the further spread of the disease. Immature fruit is frequently attacked; it becomes light brown and finally black, the flesh soft and pulpy, and the skin somewhat wrinkled. Ripe fruit seldom becomes infected.

The Characters of *Bacillus amylovorus* (Burr) de Toni.

Morphology.

Bacillus amylovorus is a short rod with rounded ends, $\cdot 9$—$1\cdot 5\mu \times \cdot 7$—$1\mu$ in dimensions, longer (nearly up to 3μ) and slightly narrower in old cultures.

It is motile by means of several (4—8) peritrichous flagella; no capsules or spores have been observed. The rods are usually single or in pairs, but in young cultures short chains made up of 3—4 individuals have been noted.

The organism is Gram-positive.

Cultural Characters.

Nutrient agar colonies are evident on the second and attain a diameter of 2—3 mm. by the fourth or fifth day. They are white and granular, or cloudy with a sharply defined white centre; the margins are entire or slightly wavy. Submerged colonies are opaque, yellowish-white, lenticular.

Nutrient agar stab. Growth takes place along the entire length.

Nutrient agar streak. In 24 hours there is a moderate opalescent growth which spreads slowly. It is finally white, wet-shining, thin along the middle, heavier along the sides, margins wavy, eventually spreading over the surface of the slant. More rapid growth is induced by the addition of the agar of 2 % saccharose, dextrose or maltose or 5 % glycerine. The water of condensation becomes turbid, but the growth is not viscid.

Nutrient gelatine colonies are very slow growing, only appearing after 3—5 days. The surface colonies are round, slightly raised, entire, buried colonies spherical, granular. The medium is liquefied very slowly.

Nutrient gelatine stab. Growth is at first filiform, and is slow and feeble; surface growth spreading with irregular margin; slow crateriform liquefaction takes place, later becoming stratiform.

Nutrient bouillon is clouded after 24 hours and this is accompanied by a slight acidity; after 48 hours there is greater cloudiness with more or less persistent flocculi, the medium becoming alkaline, and in time showing a tendency to clear. In sugar-free bouillon the liquid remains clear for 24 hours except for a slight sediment. It is neutral at first, becoming cloudy and alkaline after some days. The clouding is never very heavy as compared with other organisms.

Milk is coagulated in 3—4 days; coagulation is followed by digestion to a pasty or sub-gelatinous condition, with separation of supernatant whey; this is at first acid, later becoming slightly alkaline. Litmus milk is unchanged.

Blood serum. On this medium the growth is similar to that on nutrient agar; there is no liquefaction.

Potato, carrot, turnip, beet. There is good growth on all these media; it is best on beet, weakest on turnip. In all alike a wet-shining white streak forms along the line of inoculation; the liquid is heavily clouded, white and nearly opaque. The tissues are not softened and there is no odour, gas or pigment.

Cohn's solution. No growth.

Dunham's solution. The organism grows rapidly in this solution, but the clouding is not dense; there is no pellicle or rim and the deposit is slight.

Uschinsky's solution. Growth copious but not viscid.

Biochemical and Physical Relations.

Enzyme production: Amylase. Amylolytic activity is indicated by the fact that the organism liquefies starch jelly.

Gas. No gas is produced in fermentation tubes with glucose, saccharose, lactose, glycerine, maltose or mannite.

Pigment. None, organism is white or greyish white on all media.

Indol. A considerable amount of indol is produced.

Acid and *alkali production.* Ordinary nutrient broth shows a slight decrease of alkalinity, then a return to the original reaction. Broth containing 2 % saccharose or glucose, gradually became acid; lactose broth showed little or no change in two weeks.

Nitrates are not reduced to nitrites.

Colour reduction. Litmus milk and rosolic acid peptone water showed progressive bleaching during the first week, but the colour finally returned.

Toleration of sodium chloride. 3 % did not inhibit growth.

Temperature relations. The optimum temperature is 25—30° C.; there is no growth at 5° C.; growth is very slow at 3° C. Thermal death point (wet) is 43·7° C., 10 minutes exposure.

Desiccation. When organism was dried on cover glasses at about 20° C., 5 days had no effect, 76 days was fatal.

Insolations. 10 minutes exposure of freshly poured plates retarded development; 30 minutes was fatal.

II. BLOSSOM BLIGHT IN ENGLAND CAUSED BY BARKER AND GROVE'S ORGANISM.

This disease is very widespread in England, probably occurring at least throughout the midland and southern counties. The most susceptible varieties are the Beurre d'Amanlis and the Catillac.

The method of infection varies; sometimes the sepals turn grey and blacken, the discoloration finally involving the whole of the calyx and flower stalk, and the flower blackens and shrivels up. It may then fall or it may remain attached to the shoot. The whole truss of blossom eventually dies and the spur may also die back to its point of attachment to the branch carrying it. In other cases infection takes place through the receptacle, which becomes blackened, the discoloration spreading to the ovary.

The disease is carried from flower to flower by bees. An organism has been isolated and the disease reproduced repeatedly by Barker and Grove in the course of their study of the disease; and I was successful in producing black spots on the receptacle with the culture which they sent to me; these latter developed rather slowly as the room temperature was far above the optimum for the organism.

In a recent report (2) it is stated that an organism has been isolated from diseased gooseberry bushes which is in all probability identical with the organism causing the pear blossom blight.

The Organism.

A parallel series of cultures of this and the South African organism have been carried out; the characters of Barker and Grove's organism are described in some detail in their paper (1) but a few additional points of interest have been observed in making the comparative study, which may be added to their description.

Morphology.

The organism is a rod 2—4 × ·5—·8μ, the cells are mostly single or in pairs, seldom in long chains. It is highly motile in young cultures by 2—5, lophotrichic flagella (Fig. 1) which are four to five times as

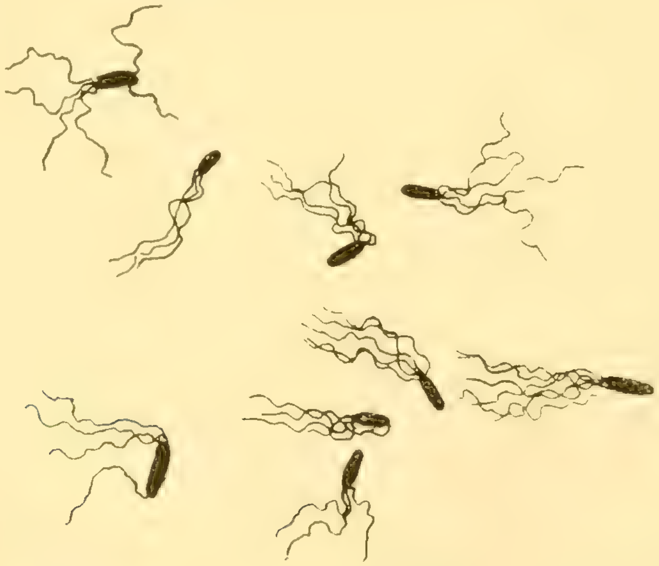

Fig. 1. Barker and Grove's organism 24 hrs. at 20° C. Ellis' flagella stain. Zeiss obj. $\frac{1}{12}$, No. 12 compensating ocular. Drawn with the aid of the camera lucida.

long as the rods. No capsules have been observed. Involution forms are produced in 24 hours in nutrient broth at 30° C. and in old cultures; these take the form of long threads up to 100μ long and irregularly swollen.

It stains well with all the usual stains, especially with Gentian violet and is Gram-positive.

Cultural Characters.

Nutrient agar colonies. At 18°—20° C. the colonies are visible to the naked eye in 48 hours; in three days the surface colonies are ·5 to 3 mm. in diameter, round-irregular, glistening and translucent; in four days they are up to 5 mm. in diameter, of a light coppery tint by transmitted light, creamy white by reflected light. Some of the colonies are inclined to spread and become lobulate, but the majority are more or less circular, with a smooth margin.

The submerged colonies are at first punctiform, afterwards lenticular. There are a few crystals in old cultures.

Nutrient agar streak. Cultures form a flat, whitish glistening growth, spreading out at the base of the slant; very old streaks are slightly fluorescent.

Nutrient agar stab. The best growth is at the top.

Nutrient gelatine colonies. Visible in 48 hours; the submerged colonies are minute white points; those on the surface slightly larger, with an undulate margin around which there is a slight indication of liquefaction. After four days the surface colonies are sunk in small craters of liquefied gelatine, they are moist and glistening semi-transparent, often with a small white nucleus in the centre, surrounded by several concentric rings of whitish, granular matter. Liquefaction of the gelatine is complete in 8—10 days.

Nutrient gelatine stab. In three days at 18—20° C. there is a small crater of liquefaction 4—8 mm. broad and 8—10 mm. deep, and the surface growth has sunk to the bottom of the crater; in seven days the liquefaction involves the whole thickness of the tube and becomes stratiform.

Potato. On this medium there is a raised, creamy-white growth with smooth edges along the needle track.

Turnip. No growth.

Carrot. The growth on carrot is very scanty, thin, and spreading.

Parsnip. A very much raised, shining streak develops, standing about 2 mm. high, the surface being almost semi-cylindrical; on one cylinder the edges only were raised and the centre depressed.

Beet. On beet the organism grows fairly well, producing a raised, gelatinous-looking growth along the needle track; the growth on the surface of the liquid takes up the colour from the medium to some extent and becomes fairly pink.

Blood serum. The organism does not liquefy blood serum, and the streak is similar to that on nutrient agar, but the growth less copious.

Nutrient bouillon becomes slightly clouded in 24 hours, and in two to three days is fairly heavily clouded. There is a considerable amount of sediment and a very thin pellicle. In very old cultures a slight fluorescence may sometimes be observed.

Milk is not curdled, but is very slowly peptonised. In nine days two-thirds to four-fifths of the liquid is clear; after one month the milk is completely peptonised, the colour is reduced in litmus milk, and the medium is distinctly alkaline to litmus.

Dunham's solution is slightly clouded.

Uschinsky's solution. No growth.

Cohn's solution. No growth.

Nutrient bouillon over chloroform. Growth was unrestrained in the presence of chloroform.

Egg albumen. A medium composed of 1 gram powdered egg albumen and 50 c.c. of ·05 % potassium phosphate was well clouded in five days.

Physical and Biochemical Relations.

Proteolytic activity. The organism is a fairly active proteolytic agent; it slowly peptonises milk and there is a distinct smell of ammonia from liquefied gelatine.

Cultures in nutrient bouillon were tested for ammonia by distillation after five to 10 days at 20° C. In each case 50 c.c. of medium were found to contain approximately ·02 gramme of ammonia nitrogen.

In the egg albumen medium described above there was a positive reaction for peptone after five days. A quantitative test by Sorensen's method showed that 50 c.c. of the medium after five days contained ·0035 nitrogen, in the form of amino acids and ammonia, *i.e.* approximately 2·3 % of the total nitrogen had been broken down. A distillation test for ammonia showed that the whole of this was in the form of ammonia; and cultures tested after 10 days gave an almost identical reading; the amount of ammonia had not increased.

Milk cultures tested in the same way gave a strong reaction for peptone and for tyrosin after 10 days; and there was ·011—·017 grains ammonia nitrogen in 50 c.c. of the medium.

Amylolytic action. Starch is very slowly destroyed; nutrient bouillon containing ·01 gram of soluble starch gave the red-brown reaction of amylodextrin with Lugol's iodine solution after about 10 days, and in three weeks the starch had completely disappeared.

Fermentation reaction. No acid or gas was produced in fermentation tubes containing peptone water, tinted with litmus, and containing 2 % of any one of the following substances:—starch, laevulose, mannite, glycerine, galactose, saccharose, dextrose, lactose.

Indol. No reaction for indol was obtained at room temperature in 10 days old cultures in peptone water and nutrient broth, but after warming a slight, but quite definite coloration appeared after the addition of sulphuric acid and a nitrite.

Nitrates are not reduced to nitrites.

Gas production. It has been mentioned that no gas is produced in fermentation tubes containing sugar solutions. In iron and lead peptone solution and bouillon the precipitate was decidedly blackened, showing that sulphuretted hydrogen had been liberated.

Atmospheric conditions. The organism is a facultative anaerobe; it grows slowly on glucose formate agar in an atmosphere devoid of nitrogen.

Temperature. The optimum temperature lies between 15 and 20° C.; the thermal death point has not yet been determined.

III. THE SOUTH AFRICAN DISEASE.

It has already been pointed out that so far as is known at present the pear blossom blight only occurs in the Stellenbosch District and at Elsenberg, that is to say in the region where the winter and early spring is the rainy season and in that part of it where pears are extensively grown. Several cases of blackening in blossoms and pearlets grown in other parts of the country have been brought to our notice, but as these occurred in hot dry weather after some six or seven months' drought, it is more probable that the failure of the blossoms was due in these cases to drought than to the bacterial blight, which only spreads rapidly when the atmosphere is moist. Further investigation, however, will be necessary before any definite statement as to the geographical distribution of the disease can be made.

Varieties affected.

Some of the late flowering varieties are the most susceptible. Winter Nelis and Beurre Superfine are very badly affected, also the Kastanje Bergamot; a number of other varieties including the Keiffer, Beurre Diel and Bon Chrétien are also affected but not to the same extent as those above mentioned. The Duchesse d'Angoulême appears to be practically immune, as no sign of the disease could be found on trees standing in an adjacent row to a number of Keiffers which were badly affected.

Symptoms and spread of infection.

So far as can be ascertained up to the present the disease is confined to the flowers, peduncles and very young fruits. No infections have as yet been found on leaves or twigs, and I have failed to produce artificial infections on these parts.

Infection almost invariably takes place through the receptacles; it usually takes place at more than one spot, a number of minute dark spots appear on the receptacle, these rapidly increase in size, becoming black and spreading until the whole receptacle is involved. Less frequently the tissues of the receptacle are very completely invaded before any blackening occurs, the whole assuming a greenish brown, water-soaked appearance and later turning black.

When the receptacle is invaded the infection and blackening frequently spreads to the styles and the ovary, and less frequently to the flower stalk. Infected flowers fall, and in the case of susceptible varieties in such numbers as to seriously affect the crop.

The rapidity with which the disease spreads from flower to flower suggested that the infection is carried through the agency of bees. With the assistance of Mr Neethling, the lecturer in Botany at the Elsenberg Agricultural College, this point was satisfactorily settled. He kindly co-operated with me in this matter by capturing a number of bees which were working in the neighbourhood of the infected trees; some of these were allowed to walk over some nutrient agar and then released; from others the mouth parts were excised, and dropped into tubes of melted agar which were then set on the slant. The tubes thus infected were then posted to me at Pretoria for examination.

Cultures of the causal organism were readily obtained from all five of the tubes containing the bee traces; of the others the organism was found in one into which the head and prothorax of the bee had been dropped, but not in any of the tubes planted with the proboscis or mandibles alone.

Artificial infections were readily produced with the culture isolated from the bee traces.

It seems possible that ants may also be partly responsible for carrying infections, as quite a number of them were noticed working in the infected flowers at one farm in the Stellenbosch District.

Etiology.

When the organism causing the bacterial blight in pear blossoms was first isolated in October 1915, the blossoming season in Pretoria was almost at an end, but a preliminary infection experiment was carried out with the few flowers which were still to be found on the trees. The blossoms sent from Stellenbosch were shrivelled and quite black, but bacteria were very plentiful in the tissues and no difficulty was experienced in obtaining a pure culture.

The weather was exceedingly hot and dry so that it was useless to attempt any inoculations in the orchard. A number of twigs bearing apple and pear blossoms were therefore carefully cut under water, and conveyed to the laboratory where they were covered over with bell jars; some of these were atomised with a suspension of a culture in sterile distilled water, others kept as controls. The latter remained fresh and showed no signs of drooping or discoloration during the experiment. The inoculated blossoms, however, showed water-soaked spots on the petals, calyx, and peduncle after 24 hours; in 48 hours these had become very numerous and began to turn brown, and in a few days the whole flower had turned black and fallen.

The organism was readily re-isolated and inoculated into some young pears by atomising as before; a few infections were thus obtained in pearlets which had just set, but not on the fruit of the size of a walnut or larger; that is to say, the organism seemed unable to attack the young fruit after it had begun to harden.

After visiting the affected orchards in September, 1916, fresh cultures were obtained from material collected, and a number of inoculations were carried out with the organism thus freshly isolated, the strain isolated the previous year and with Barker and Grove's organism. Inoculations were carried out in one of three ways; the flower was infected by touching the receptacle with a platinum needle, which had been charged with a small quantity of agar culture; a drop of a suspension of an agar culture was placed on the receptacle with a fine pipette;

or the whole inflorescence was atomised with a suspension of an agar culture in distilled water.

When either of the first two methods was employed a number of minute water-soaked spots appeared on the receptacle in 24—48 hours, or, in the case of a heavy infection the whole receptacle became water-soaked in appearance.

The infected areas soon began to turn brown and spread until the whole receptacle was involved. The receptacle was finally quite black, the blackening not infrequently spreading into the styles, ovaries and peduncle; and the slightest movement was sufficient to cause the infected flowers to fall.

When the inflorescence was atomised, infection was equally prompt, discoloured areas appearing on the sepals, petals, ovary and peduncles. In no case have I been able to infect the leaves or fruit spurs, and I have not observed any such infections in the orchards.

All inoculations were carried out in the Laboratory under conditions similar to those employed during the preliminary experiment carried out in 1915; a schedule of the inoculations is appended.

It will be noticed that positive results were obtained in each case when pear and apple blossoms were inoculated, but that attempts to infect cherry, peach and nectarine were all unsuccessful. Up to the present no natural infections on the apple have been found.

In each experiment an equal number of flowering branches were kept as controls; and in no case did the disease appear in these.

No.	Kind of Blossom	Method	Source of Culture	Results
1	Pear	Atomiser	Blossoms from Banhoek, Stellenbosch	Positive
2	Apple	,,	,, ,,	,,
3	Pear (young fruits)	,,	Re-isolated from (1)	,,
4	Pear	Platinum needle	Blossoms from Elsenberg	,,
5	,,	Pipette	,, ,,	,,
6	,,	Atomiser	,, ,,	,,
7	Cherry	Pipette	,, ,,	Negative
8	Pear	,,	As (1) but after 12 months in cultivation	Positive
9	,,	,,	Blossoms from Ida's Valley, Stellenbosch	,,
10	,,	,,	Re-isolated from (4)	,,
11	,,	Atomiser	Same as (4)	,,
12	Peach	Pipette	,, ,,	Negative
13	Nectarine	,,	,, ,,	,,
14	Pear	,,	,, ,,	Positive
15	,,	,,	Bee traces	,,

Pathological Histology.

Infection usually takes place through the nectaries, but the organism sometimes finds its way into the green tissues of the flower and flower stalks through the stomata.

The rods multiply very rapidly in the intercellular spaces, and it is very noticeable that wherever the intercellular spaces are invaded, the contents of the adjacent cells become plasmolysed and stain very deeply with carbol fuchsin. In sections stained with carbol fuchsin and light green these showed up in startling contrast to the normal cells which stained light green and in some of which the nucleus could be plainly seen (Fig. 2).

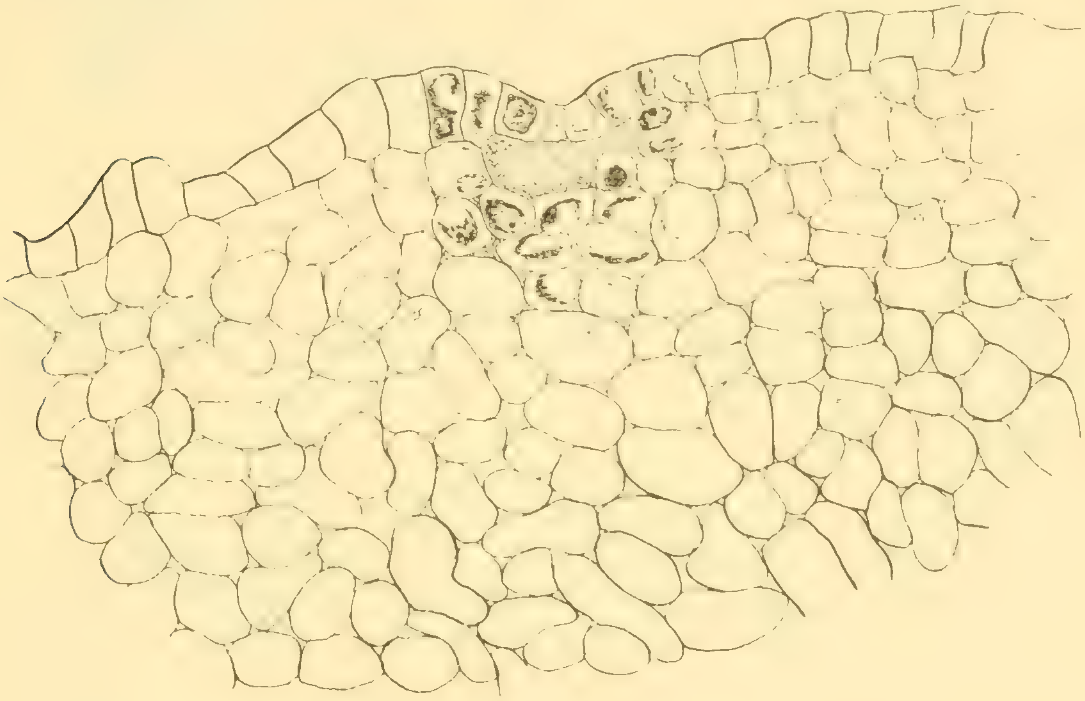

Fig. 2. Section through diseased receptacle, natural infection, drawn with Edinger's projection apparatus. An early stage of infection.

After the cells are plasmolysed and killed they disintegrate very rapidly and collapse, the original cell outline completely disappears and the diseased area consists of a disorganised mass staining intensely with carbol fuchsin.

When the receptacle is infected the flowers soon fall, but in some cases not until the infection has spread into the more deep-seated tissues of the ovary, all of which become blackened and disorganised (Fig. 3).

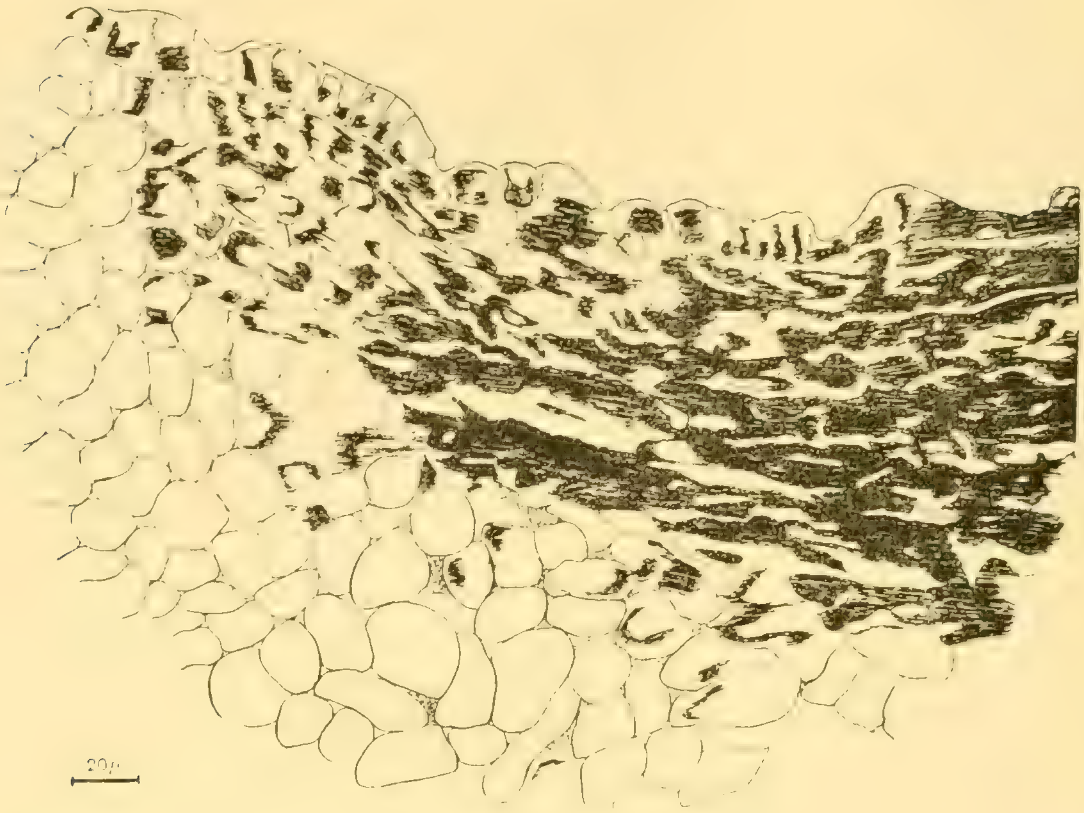

Fig. 3. Section through diseased receptacle, natural infection, drawn with Edinger's projection apparatus, the scale is indicated. A more advanced infection showing the collapsed tissues.

Morphology.

The organism is a short rod of very variable size and shape. A pure culture may be readily obtained from infected tissues, but the milky white masses of bacteria which diffuse out from such tissues consist of rods which exhibit astonishing variations in size and form (Fig. 6). The majority are short thick rods with rounded ends, measuring for the most part $\cdot 6$—$1\cdot 5 \times \cdot 5$—$\cdot 7\,\mu$, but all the variations found on various culture media may be seen. In addition to these there are undivided rods up to $12\,\mu$ long, which are sometimes irregular in shape but which stain intensely with carbol fuchsin; it would seem probable that these are involution forms of some sort, although nothing resembling them has been found in artificial culture media. The same remark applies to fairly numerous rods of various lengths which stain faintly and are only about $\cdot 2\,\mu$ in diameter. All the rods are distinctly capsuled, and many of them are not stained evenly, showing 1—2 or, in the larger individuals, as many as 5—6 colourless vacuoles.

Young cultures on agar (24 hours at 25° C.) show very similar characters to those described above (Fig. 4) with the exception of the two abnormal forms just mentioned. The size of the rods is very variable, some are almost spherical, the limits of size being ·5—3μ × ·45—·7μ; the majority are 1—1·5 × ·6—·65μ. They are usually single or in pairs but chains of 5—10 are fairly frequent, and these are peculiar in that the rods are not as a rule placed uniformly end to end, but are

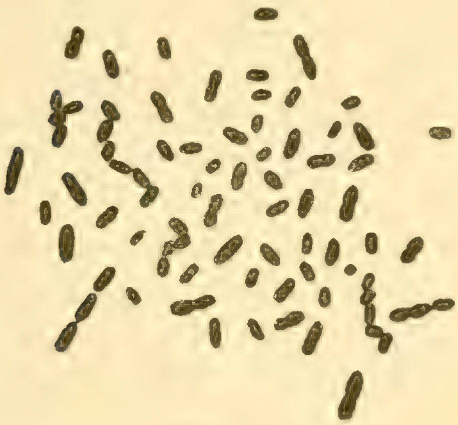

Fig. 4.

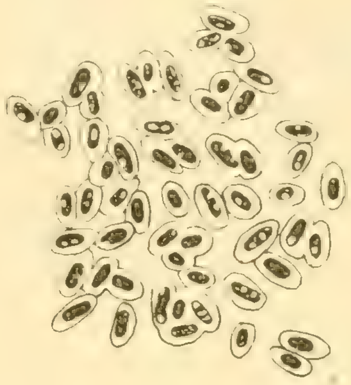

Fig. 5.

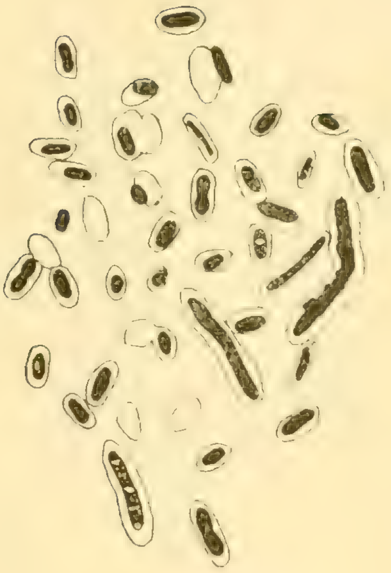

Fig. 6.

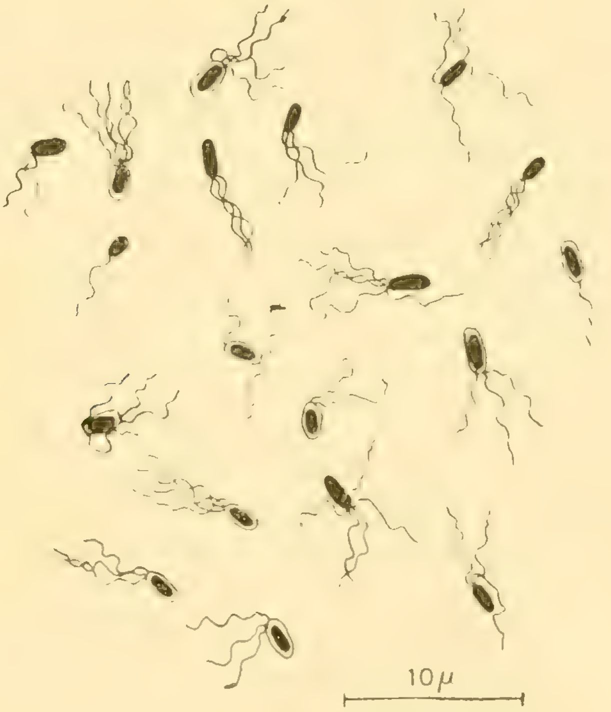

Fig. 7.

Figures 4–7. *Bacterium nectarophilum*; magnification same as Fig. 1. Fig. 4. 24 hrs. at 25° C. on nutrient agar. Fig. 5. Uschinsky's solution, 7 days at 25° C. Fig. 6. Direct from host plant. Fig. 7. 24 hrs. at 25° C., Ellis's flagella stain.

quite as frequently obliquely, or are attached almost laterally (Fig. 4). One or two vacuoles, the contents of which do not stain with carbol fuchsin, can be seen in many individuals; that these non-staining areas are not due to plasmolysis is proved by the fact that they can be clearly seen in the living condition with the dark ground illumination, by which means also the capsule is plainly visible. The capsule stains readily with carbol fuchsin or gentian violet, and is very obvious around rods from the condensation water in tubes containing nutrient agar cultures about four days old. The growth in the condensation water is very viscid, in consistency almost like egg albumen; short rods and almost coccus-like forms predominate. These stain intensively with carbol fuchsin, are surrounded by a colourless capsule and are embedded in a slimy matrix which stains faintly.

After four weeks at 25° C. on nutrient agar only a small percentage of the rods stain intensely, the staining of the majority being very faint and uneven.

In broth cultures the prevailing forms are slightly longer than those on agar, rods 2—2·5μ long being frequent; the vacuolation is distinct.

Very characteristic rods are found in Uschinsky's solution (Fig. 5). Capsuled bacteria form a pellicle on the surface of the fluid; this sinks when disturbed and forms a sediment. The capsule is very conspicuously developed, and the growth is viscid in character like that described in the condensation water at the base of agar streaks; each rod has one, two or more distinct vacuoles.

The organism is actively motile in young cultures (less so as it diffuses out from the tissues of the host) by means of 1—5 polar flagella; these are two to three times the length of the rod, and are occasionally bi-polar but most frequently they are only at one pole. The flagella stain quite readily by Ellis's modification of Loffler's method (Fig. 7).

Staining reactions.

Carbol fuchsin is undoubtedly the best stain for this organism, although it stains well with all the usual stains. It does not stain by Gram's method, and is not acid fast.

Cultural characters.

Nutrient agar (+15). Colonies are visible after 24 hours at 25° C. as thin milky-white growths 1—3 mm. in diameter and rather irregular in shape; after 48 hours, surface colonies are 1—2 cm. diameter, in thinly sown plates, spreading, sub-circular to irregular in shape, the edges being auriculate-lacerate; they are coppery by transmitted light, creamy white to light dull, green yellow[1] by reflected light. In crowded plates the colonies are small and somewhat raised; submerged colonies are very small and are lenticular in outline. A greenish fluorescence may always be observed from agar media on which this organism has been grown; frequently this is very marked, and in thickly sown plates can be detected after 24 hours' growth. This characteristic appears to vary with the composition of the medium, and the conditions under which the organism is grown; it is more marked when the organism has been in cultivation for some time than when it is newly isolated, and also appears to be more conspicuous in cultures which have been exposed to the light; slight variations in the composition of the medium are also probably responsible in some degree for variations of this kind. No crystals have been seen in old cultures. Under the microscope the texture of the surface colonies is homogeneous and very finely granular.

Nutrient agar (+ 15). Streak cultures on nutrient agar are wet-shining, yellowish white, flat smooth, undulate at the edges, and inclined to spread over the wetter parts of the medium. No crystals are formed. There is always more or less fluorescence from the agar, but, as observed in connection with the plate cultures, it is variable. Sometimes there is a distinct greenish fluorescence from the agar and the bacterial growth at the end of 24 hours; sometimes it is not marked until the culture is five or six days old; it is more noticeable when the tubes have been exposed to the light. The growth in the condensation water is very viscid.

Nutrient agar. Stab. The best growth takes place at the top.

Dextrose agar. Streaks were also made on nutrient agar to which 2 % dextrose had been added. On this medium the growth was slightly heavier than on ordinary nutrient agar; it was opaque, creamy white, and the medium was rendered opaque, in contrast to ordinary nutrient agar which remains translucent and exhibits a greenish fluorescence.

Hiss glucose medium produced a very similar growth to that on dextrose agar, but it was more noticeably viscid, drawing out into fine threads on the platinum needle.

Nutrient agar + 2 % dextrose and litmus. The streak is similar in character to that described on nutrient agar with dextrose, but striking colour changes may be observed in the medium. On the sixth day the agar, which was a neutral litmus tint when planted with the organism, is Killarney green, when viewed by transmitted light facing the streak; viewed by transmitted light facing the side of the slant the colour is deep red, nearest Nopal red. By reflected light the upper part of the agar is still green, but from the deeper layers there is a distinctly purplish light reflected. There was no further change in colour during the six weeks the tubes were kept under observation.

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[1] Colours are named according to Ridgway's *Colour Standards and Nomenclature* and have been carefully compared with colour charts in that publication.

Loffler's blood serum is not liquefied, a streak culture on this medium is similar to that on nutrient agar.

Cabbage agar. On this medium the organism forms a ribbon-like streak, honey yellow, 3—4 mm. broad, and with a wrinkled shagreen surface.

Nutrient gelatine (+ 15). Colonies at 20° C. attain a diameter of about 4 mm. in three days; they are thin, spreading, with a slightly irregular margin, in the centre of each colony there is a small, glistening, raised point; the remainder of the growth has a dull, ground glass appearance. Submerged colonies are small, yellowish opaque.

There is no liquefaction, and colonies do not change further, except to increase in size in thinly sown plates. There is no fluorescence in this medium.

Nutrient gelatine stab. There is a growth similar to the gelatine colonies, covering the surface of the medium and a filamentous growth along the upper part of the medium; but no liquefaction during two months and no development in the depths of the medium.

Nutrient gelatine streak is flat, about 4 mm. broad with undulate or crenate margin; here also the growth is dull and thin, and has the appearance of ground glass when held up to the light.

Nutrient bouillon (+ 15) is heavily clouded in 24 hours at 20° C., and afterwards becomes very turbid. There is a tendency to pellicle formation, but when disturbed the pellicle breaks up into flocculi and sinks. A greenish fluorescence may be observed, and is usually very noticeable especially from the surface of the medium. A considerable amount of rather viscid sediment collects at the bottom of the tube or flask.

Nutrient bouillon + 2 % dextrose. The growth in this medium is heavier than in nutrient broth to which no sugar had been added, but the broth does not become fluorescent.

Nitrate bouillon becomes heavily clouded, and there is a thick pellicle, but the fluorescence is not marked.

Dunham's solution is not a very favourable medium and does not become very densely clouded; a slightly heavier growth was observed in peptone water to which potassium nitrate had been added.

Nutrient bouillon over chloroform; growth was unrestrained in the presence of chloroform; the tubes were clouded in 24 hours, turbid in 48 hours.

Litmus milk is slowly peptonised. After 24 hours at 25° C., the fluid is clear to a depth of about 2 mm. from the surface, the remainder of the milk being unchanged. After 5—6 days the upper third of the medium is clear and translucent, the middle third is partially peptonised, and the remainder still opaque and unchanged; the medium thus exhibits three strata of approximately equal depth. In 8—10 days the whole of the milk has been peptonised, the colour is at first unchanged by reflected light and reddish by transmitted light, but it finally becomes slowly reduced from the top downwards leaving a yellowish translucent fluid. There is a small amount of sediment.

Egg albumen. A medium composed of 1 grm. powdered egg albumen in 50 c.c. of ·05 % potassium phosphate was used to determine the proteolytic activity of the organism. The medium after sterilisation is a colourless liquid in which the insoluble part of the egg albumen has been separated out in white flakes; when planted with the organism the liquid became clouded and then became deep sea foam green in colour. The solid albumen was acted upon and became slimy and soft in consistency.

Uschinsky's solution is clouded in 24 hours at 25° C., after six days it is very turbid, first the upper part of the broth, and gradually the whole of it becoming light, dull, green yellow to clear, dull, green yellow, the colour being much more noticeable by reflected than by transmitted light. There is a fair amount of sediment and the rods are normal and active. There is a ring above the medium, and a pellicle which sinks if the tube is shaken.

At the end of 20 days the pellicle still continues to form, and to sink when disturbed. A very heavy deposit is thus formed which is very viscid and almost like egg albumen in consistency. After some weeks the liquid becomes clear but yellowish; there is some yellowish growth clinging to the sides of the tube and a deposit 1—2 cm. deep in the bottom.

The organism also grows, but less vigorously, in a solution from which the asparagin and ammonium lactate have been omitted and replaced by ammonium sulphate. The organism is therefore able to obtain its nitrogen from a simple salt.

Cohn's solution. No growth.

Potato. A creamy-white, wet-shining streak about 6—8 mm. broad appears along the needle track; the edges are undulate.

Turnip. On turnip there is a thin, wet-looking, whitish growth, almost covering the slant surface.

Beet. On beet the growth is heavier than on turnip and carrot but it is not so spreading; it is yellowish and slightly raised.

Carrot. There is a very thin, whitish, wet-looking growth, in some tubes almost completely covering the slant surface; in others where the cylinder was drier only producing a streak a few millimetres wide along the needle track.

Parsnip. On parsnip there is a good growth along the needle track, 5—10 mm. wide, and slightly raised, shining.

Physical and Biochemical Relations.

Proteolytic activity. It has been pointed out in the section dealing with the cultural characters of the organism that milk is slowly peptonised. If a ten days old culture of the organism is killed by exposing it to a temperature of about 55° C. for half an hour and then 3—5 c.c. of the culture run into each of a number of tubes of sterile litmus milk, it is found that the milk is slowly cleared in precisely the same way as if the organism were growing in the medium.

A series of flask cultivations was carried out with a view to testing for the products of proteolysis. The media used were ordinary nutrient broth, egg albumen (1 gm. in 50 c.c. of ·05 % potassium phosphate) and milk; in each case 50 c.c. of the medium being sterilised in an Erlenmeyer flask of about 150 c.c. capacity. In this way the organism received abundant aeration and growth was fairly rapid.

Cultures in nutrient broth were tested for ammonia by distillation after five days at 25° C. The Nessler test could not be used owing to the presence of an appreciable amount of ammonia in the control flask.

A quantitative test showed that the amount of ammonia in the culture had not increased from the fifth to the tenth day, the difference in each case between the amount of ammonia in the culture flask and the control being ·016 grm. of ammonia nitrogen.

Egg albumen after five days at 25° C. gave a definite reaction for peptone and for tryptophane. The culture was tested by Sorensen's method for amino-acids and ammonia together at the end of the fifth and the tenth day. After five days the result was ·0148 grm. nitrogen in the form of amino-acids and ammonia: if egg albumen contains ·150 grm. (approximately) total nitrogen, then 2·8 % of the total nitrogen had been broken down; after 10 days the figures were ·007 grm. or approximately 4·6 % of the total nitrogen.

Milk cultures after ten days tested by the Sorensen method contained ·019—·022 grms. nitrogen in the form of amino-acid and ammonia. When tested by distillation for ammonia alone, practically the same figures were obtained; it was evident therefore that the amino-acids had been reduced to ammonia.

Tested qualitatively the milk culture gave a very decided reaction for peptone and for tyrosin.

The results recorded above are sufficient evidence that the organism is a fairly active proteolytic agent.

Amylolytic action. Potato cylinders on which the organism has been growing for any length of time give the red-brown reaction for amylodextrin when treated with Lugol's iodine solution rather than the deep blue starch reaction.

Tubes containing 10 c.c. nutrient bouillon and ·01 grm. soluble starch were planted with a vigorous culture and incubated at 25° C. It was between two and three weeks before the starch totally disappeared. The action of the organism on starch therefore is comparatively slow.

Invertase and *lactase* are not produced by this organism. This is shown by the fact that although the organism produces acid in solutions containing dextrose and galactose it is unable to do so in those containing lactose and saccharose. Were it capable of reducing these sugars, acid would be formed in solutions containing them.

Fermentation reactions. No gas was produced in fermentation tubes containing peptone water tinted with litmus and 2 % of various carbohydrates. The amount of growth and presence or absence of acid production may be scheduled as follows:

Carbohydrate	Acid production	Nature of growth
Dextrose	Distinctly acid after 3 days	Moderate
Dextrin	None	Very heavy
Galactose	Distinctly acid after 3 days	Moderate
Glycerine	None	Light clouding
Laevulose	,,	,, ,,
Lactose	,,	,, ,,
Maltose	,,	,, ,,
Mannite	,,	,, ,,
Saccharose	,,	,, ,,
Starch	,,	,, ,,

A quantitative test for acid production was carried out with some of the sugars mentioned above. Cultivations were prepared in bulk in flasks containing 50 c.c. nutrient broth and 2 % of the substances to be tested. They were incubated for 10 days at 20° C. and were as follows (expressed in degrees of Fuller's scale).

Sugar	Culture	Control
Dextrose	+35·5	+15·6
Glycerine	+10	+15
Lactose	0	+15
Laevulose	+10	+15
Saccharose	0	+15

It will be observed that except in the case of dextrose the culture was slightly less acid than the control.

No reaction for alcohol or aldehyde was obtained in the distillate from a culture in dextrose bouillon.

Indol. There was no indol in cultures in Dunham's solution or in nutrient bouillon after 10—12 days at 20° C. Tests for phenol were also negative.

Pigment production. It has already been pointed out in the section on the cultural characters of the organism that it produces on certain media a distinct greenish or greenish yellow fluorescence.

Colour destruction. Methylene blue was almost completely reduced in 24 hours; neutral red and rosolic acid were not reduced. Litmus was partially reduced in milk cultures but not in nutrient broth.

Nitrate reduction. Nitrates were not reduced to nitrites during ten days growth in nitrate broth and in nitrate peptone water at 25° C.

Gas production. It has been stated that no gas is produced in fermentation tubes containing various sugar solutions.

Cultivations were prepared in iron and lead peptone solution; the precipitate began to blacken after some days, that in the tubes to which iron tartrate had been added becoming decidedly black, thus showing that some sulphuretted hydrogen had been liberated.

Growth under anaerobic conditions. The organism grows very slowly in glucose formate agar in Bulloch's apparatus from which the oxygen has been absorbed. Control tubes under ordinary atmospheric conditions made a very vigorous growth.

Temperature. The optimum temperature for growth lies between 25 and 30° C. The organism grows much more slowly at 20 than at 25° C. and at 35 than at 30° C.

The thermal death point is 49° C., ten minutes exposure in thin walled test tubes containing 10 c.c. nutrient broth.

Reaction of medium. The bacterium is not specially sensitive to the reaction of the medium in which it is grown. The optimum reaction lies between + 10 and + 20 Fuller, + 15 taken as approximately the optimum for cultural purposes.

The following table will serve to indicate the extreme reactions at which growth will take place and the amount of various substances necessary to inhibit growth.

Acid or alkali	Amount to restrain growth	Amount to inhibit growth
Acetic acid	+20	+25
Citric acid	+45	+50
Hydrochloric acid	+18	+20
Malic acid	+68	+70
Oxalic acid	+35	+40
Tartaric acid	+30	+35
Sodium hydrate	+30	+55

Toleration of sodium chloride. Cultivations were made in nutrient bouillon to which varying amounts of NaCl had been added. Growth was unrestrained in tubes containing up to 4 % NaCl, meagre in those with 5 to 6 % and inhibited in those with 7 %.

Desiccation. The organism is not particularly sensitive to desiccation; cultures are readily obtained from cover slips on which the organism has been dried for six weeks; more prolonged tests have yet to be made.

Insolation. The bacterium is fairly sensitive to the action of direct sunlight. Five minutes exposure is sufficient to destroy a large percentage of the rods and ten minutes to kill them all. The exposures were made on a block of ice, to the mid-day summer sun, the plates being further protected by being covered with glass basins containing about 2 cm. of a 4 % solution of potash alum.

The growth of the organism is not restrained in the diffuse light of the laboratory.

Nomenclature.

The organism appears to be one which has not previously been described. I therefore propose for it the name *Bacterium nectarophilum* n.sp., its chief characters are as follows:

Bacterium nectarophilum n.sp., parasitic in pear blossoms, causing blackening of the receptacle and ovary, and less frequently of the sepals and flower stalks; a short rod ·5—3 μ × ·45—·7 μ, majority are 1—1·5 μ × ·6—·65 μ; rods single or in pairs, short chains are fairly frequent, capsule always present, motile by means of 1—5 polar flagella. Gram-negative.

Forms spreading yellowish-white colonies in nutrient agar, fluorescent; fluorescence absent in media containing dextrose; gelatine is not liquefied; nutrient bouillon heavily clouded; milk slowly peptonised, no change in reaction. Uschinsky's solution clouded, fluorescent, growth viscid; potato growth moderate.

Fairly active proteolytic agent; starch slowly destroyed; acid from dextrose and galactose, no gas or acid from any of the other carbohydrates tested; no indol; nitrates not reduced.

Facultative anaerobe; optimum temperature 25—30° C.; T.D.P. 49° C.

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A LIST OF COCCIDAE AFFECTING VARIOUS GENERA OF PLANTS.

By E. Ernest Green, F.E.S., F.Z.S.

For several years I have been collecting records of the Coccidae that infest different genera of plants, extracted—partly from my own collections and observations, and partly from existing publications and periodical literature. Mrs Fernald's *Catalogue of the Coccidae of the World* has, naturally, provided the foundation for such an undertaking, and Lindinger's *Die Schildlause* has afforded many additional records, as have also the supplementary catalogues issued by the U.S. Bureau of Entomology. Other papers that have been laid under contribution are too numerous to mention.

The names are entered just as they are published. The compiler does not hold himself responsible for the accuracy of the determinations.

I have found this list so useful, and such a time-saving device in my own work, that I propose to publish it, in parts, in the hope that it may prove equally useful to others engaged in similar work. When a Coccid is sent in for determination, a reference to my list immediately shows what species of that particular genus have been recorded from the plant in question. It is surprising how often this has provided a clue to the identity of the species under consideration. The list, it must be acknowledged, is far from complete and—from its nature—must remain so. Fresh records will be constantly occurring, necessitating further additions. But, with this as a foundation, it should not be difficult for individual students to keep the list up to date for themselves.

I have not attempted to keep records for individual species of plants. Nor do I consider that such an amplification of detail would repay the labour entailed. As a matter of fact, it will be found that few species of Coccidae are restricted to a single species of plant, though many of them have a distinct preference for particular genera. A list of the Coccidae found in the nests of, or associated with ants, is included.

With regard to nomenclature, I have—in the main—followed Mrs Fernald's *Catalogue*; but I have found it convenient to retain—in their broader application—such genera as *Lecanium*, *Aspidiotus*, *Chionaspis*, *Diaspis*, etc.

- ABIES (Coniferae).
  - Phenacoccus piceae.
  - Physokermes coloradensis, concolor, piceae, sericeus.
  - Lecanium sericeum.
  - Chionaspis pinifoliae.
  - Poliaspis pini.
  - Leucaspis kelloggi.
  - Aspidiotus perniciosus, ehrhorni, meyeri, abietis, ostreaeformis, tsugae, littleri.
  - Lepidosaphes abietis, ulmi-japonica.
- ABUTILON (Malvaceae).
  - Ceroplastes novaesi.
  - Lecanium hesperidum, minimum, oleae-mirandum, nigrum, oleae, hesperidum-alienum.
  - Aspidiotus rossi.
- ACACIA (Leguminosae).
  - Lophococcus vuilleti.
  - Llaveia mexicanorum.
  - Monophlebus herculus.
  - Aspidoproctus armatus, mirabilis, tricornis.
  - Icerya koebelei, natalensis, purchasi, longisetosa.
  - Callipappus immanis.
  - Asterolecanium hakeae, ventruosum, variolosum.
  - Lecaniodiaspis acaciae, africana, anomala.
  - Rhizococcus grandis, grandis-spinosior, viridis, lobulatus, bicolor, lidgetti.
  - Eriococcus multispinosus-laevigatus.
  - Kermes acaciae.
  - Sphaerococcus acaciae, obscuratus.
  - Epicoccus acaciae.
  - Phenacoccus nivalis, farnesianae.
  - Lachnodius hirtus.
  - Pseudococcus longispinus, acaciae, albizziae, farnesianae, lanigerus, robiniae, texensis, coccineus, perniciosus, iceryoides, filamentosus, solitarius, quaesitus, nitidus, globosus, swezeyi, candidus, hilli.
  - Tachardia acaciae, nigra, aurantiaca, argentina, lacca.
  - Pulvinaria paradelpha, tecta.
  - Ceroplastes africanus, egbarum, africanus-senegalensis.
  - Ceroplastodes acaciae.
  - Inglisia fossilis, vitrea.
  - Ctenochiton serratus, transparens.
  - Lecanium longulum, robiniarum, oleae, cadaverosum, leve, scrobiculatum, mirificum.
  - Cryptes baccatus.
  - Protodiaspis anomala.
  - Diaspis boisduvallii.
  - Chionaspis capensis.
  - Hemichionaspis aspidistrae.
  - Crypthemichionaspis nigra.
  - Fiorinia acaciae, rubra, rubra-propinqua.
  - Aspidiotus caldesii, ceratus, fodiens, hederae, niveus, perniciosus, camelliae, rossi, unilobis, dentilobis, acaciae, gidgei, subfervens, serratus, africanus, junctiloba, tasmaniae, conspiciendus, aurantii, dictyospermi, lataniae, quadriareolata, bipartitus, phenox.
  - Aonidia glandulosa.
  - Gymnaspis acaciae.
  - Lepidosaphes acaciae, acaciae-albida, convexa, grisea, spinifera, corticoides, wilgae, multipora, chitinosa, recurvata, intermedia, somalensis.
- ACALYPHA (Euphorbiaceae).
  - Pseudococcus virgatus.
  - Pulvinaria floccifera.
  - Pseudoparlatoria ostreata.
- ACER (Aceraceae) 'Sycamore,' 'Maple,' etc.
  - Palaeococcus fuscipennis.
  - Eriococcus aceris.

- ACER (Aceraceae)—*cont.*
  - Phenacoccus acericola, aceris.
  - Pseudococcus comstocki.
  - Pulvinaria acericola, horii, hunteri, innumerabilis.
  - Lecanium aceris, canadense, cerasifex, crawi, nigrofasciatum, rugosum, tiliae, websteri-mirabile, corni.
  - Chionaspis platani, salicis.
  - Hemichionaspis aspidistrae.
  - Leucaspis japonica.
  - Aspidiotus abietis, ancylus, comstocki, fernaldi-albiventer, forbesi, hederae, juglans-regiae, ostreaeformis, perniciosus, camelliae, tenebricosus.
  - Parlatoria pergandei, theae.
- ADENOSTOMA (Rosaceae).
  - Lecaniodiaspis rufescens.
  - Eriococcus adenostomae.
  - Lecanium adenostomae.
- ADIANTUM (Filices) 'Maidenhair Fern.'
  - Pseudococcus longispinus.
  - Ripersia glandulifera.
  - Lecanium hesperidum, hemisphaericum, oleae.
  - Pulvinaria floccifera.
  - Chionaspis dubia.
- AESCULUS (Hippocastanaceae) 'Horse-chestnut.'
  - Cerococcus parrotti.
  - Phenacoccus aceriola, hystrix, aceris.
  - Pulvinaria horii, innumerabilis.
  - Lecanium aesculi, coryli.
  - Aspidiotus aesculi, ostreaeformis, ohioensis, perniciosus.
  - Lepidosaphes ulmi.
  - Diaspis pentagona.
- AGAVE (Amaryllidaceae).
  - Gymnococcus agavium.
  - Pseudococcus ephedrae.
  - Ceroplastes ceriferus.
  - Lecanium oleae, nigrum.
  - Hemichionaspis minor.
  - Aspidiotus hederae, agavis, aurantii, bowreyi, dictyospermi, ficus, lataniae.
  - Lepidosaphes nigra, philococcus.
  - Opuntiaspis javanensis.
- AGLAIA (Meliaceae).
  - Pseudoparlatoria argentata.
  - Aspidiotus gracilis.
  - Aonidia viridis.
  - Lepidosaphes travancoriensis.
- AGONIS (Myrtaceae).
  - Eriococcus agonis.
  - Sphaerococcus rugosus.
  - Chionaspis agonis.
- AGROPYRON (Gramineae).
  - Pseudococcus pulverarius.
  - Trionymus perrisii, violascens.
  - Parafairmairia bipartita.
  - Aclerda subterranea.
  - Eriopeltis festucae.
  - Antonina purpurea.
- AGROSTIS (Gramineae).
  - Eriococcus insignis.
  - Pseudococcus walkeri, pulverarius.
  - Ripersia corynephori.
  - Eriopeltis festucae.
- AILANTHUS (Simarabaceae).
  - Diaspis rosae, pentagona.
  - Lepidosaphes ulmi.
- ALBIZZIAE (Leguminosae).
  - Pseudococcus albizziae, perniciosus, capensis, filamentosus, longispinus.
  - Lecanium longulum, elongatum.
  - Ceroplastes subsphaericus.
  - Tachardia albizziae, lacca.
  - Hemichionaspis minor.
  - Aspidiotus hederae.
- ALLAMANDA (Apocynaceae).
  - Ceroputo barberi.
  - Lecanium mangiferae.
- ALNUS (Betulaceae) 'Alder.'
  - Gossyparia spurius.
  - Phenacoccus farinosus, aceris.
  - Pulvinaria betulae-alni, ehrhorni, innumerabilis, goethei, occidentalis, innumerabilis-betheli, vitis.
  - Lecanium alni, corni, coryli.
  - Chionaspis lintneri, salicis, wistariae.
  - Aspidiotus ostreaeformis, perniciosus, alni.
  - Lepidosaphes ulmi.

- ALOCASIA (Araceae).
  - Pseudococcus longipes.
  - Pinnaspis buxi.
  - Hemichionaspis aspidistrae.
  - Aspidiotus destructor.
- ALOE (Liliaceae).
  - Chionaspis exalbida.
  - Aspidiotus hederae, cladii, dictyospermi, mammillaris.
- ALSTONIA (Apocynaceae).
  - Lecanium viride, oleae.
  - Vinsonia stellifera.
  - Lepidosaphes alstoniae.
- AMELANCHIER (Rosaceae).
  - Phenacoccus cockerelli, betheli.
  - Lecanium kansasense.
  - Chionaspis lintneri, salicis-nigrae.
  - Aspidiotus fernaldi-albiventer, perniciosus.
  - Lepidosaphes ulmi.
- AMMOPHILA (Gramineae).
  - Pseudococcus hibernicus.
  - Aspidiotus provincialis.
- AMPELOPSIS (Vitaceae).
  - Lecanium magnoliarum, nigrum.
  - Aspidiotus perniciosus, tasmaniae.
- AMYGDALUS (Rosaceae) 'Peach,' 'Almond,' etc.
  - Asterolecanium pustulans.
  - Phenacoccus aceris.
  - Pulvinaria amygdali.
  - Lecanium armeniacum, canadense, cerasifex, cockerelli, persicae, pruinosum, prunastri, rugosum, hemisphaericum, nigrofasciatum.
  - Epidiaspis piricola.
  - Chionaspis furfura.
  - Diaspis leperii, pentagona.
  - Aspidiotus ancylus, forbesi, juglans-regiae, ostreaeformis, perniciosus, camelliae, africanus, cyanophylli.
  - Pseudoparlatoria parlatorioides.
  - Parlatoria calianthina, proteus.
- ANACARDIUM (Anacardiaceae).
  - Ceroplastes floridensis.
  - Aspidiotus personatus, sylvaticus, replicatus.
- ANANASSA (Bromeliaceae) 'Pine-apple.'
  - Pseudococcus bromeliae, ananassae, citri.
  - Diaspis bromeliae, boisduvallii.
  - Aspidiotus bromeliae.
  - Pseudischnaspis bromeliae.
- ANDROMEDA (Ericaceae).
  - Ceroplastes floridensis.
  - Chionaspis salicis.
- ANDROPOGON (Gramineae).
  - Eriococcus kemptoni.
  - Aclerda californica, obscura.
  - Lecanium tenuivalvatum.
  - Chionaspis graminis.
  - Aspidiotus marlatti.
- ANGRAECUM (Orchidaceae).
  - Conchaspis angraeci.
  - Asterolecanium aureum, epidendri.
- ANONA (Anonaceae) 'Custard-apple,' Sour-sop,' etc.
  - Icerya albolutea.
  - Asterolecanium pustulans.
  - Tachardia lacca, decorella.
  - Pseudococcus citri, capensis.
  - Stictococcus dimorphus, diversiseta.
  - Ceroplastes denudatus, floridensis, quadrilineatus, ugandae, rusci.
  - Inglisia conchiformis.
  - Lichtensia crescentiae.
  - Lagosinia strachani.
  - Lecanium longulum, marsupiale, hemisphaericum, nigrum, viride.
  - Howardia biclavis.
  - Diaspis miranda.
  - Aspidiotus cyanophylli, destructor, translucens, gowdeyi.
- ANTHURIUM (Araceae).
  - Asterolecanium aureum.
  - Ceroplastes floridensis.
  - Lecanium angustatum, anthurii, nigrum, hesperidum.
- ANTIDESMA (Euphorbiaceae).
  - Kuwania zeylanica.
  - Lecanium antidesmae, oleae, planum.
  - Ghionaspis flava, acuminata.
  - Dinaspis permutans.
  - Aspidiotus rossi.
- ANTIGONON (Polygonaceae).
  - Ceroplastes ceriferus.
  - Pulvinaria antigoni.
  - Lecanium hemisphaericum.

ANTS' NESTS.
Stigmacoccus asper, ferox.
Icerya formicarum.
Orthezia lasiorum, occidentalis, cataphracta, floccosa, olivacea.
Ortheziola vejdovskyi.
Anomalococcus cremastogastri.
Rhizococcus texanus.
Eriococcus apiomorphae.
Ceroputo lasiorum.
Natalensia fulleri.
Tylococcus madagascariensis.
Micrococcus silvestrii, oviformis.
Phenacoccus americanae, glacialis, ripersioides, hirsutus, formicarum.
Pseudococcus claviger, cockerelli, formiceticola, hirsutus, neomexicanus-indecisus, sorghiellus, myrmecarius, sorghiellus-kingi, wheeleri, cycliger, flagrans.
Ripersia arizonensis, aurantia, blanchardi, cockerellae, confusella, europaea, fimbriatula, flaveola, formicicola, kingi, lasii, minima, montana, subterranea, tomlini, trivittata, tumida, globata, viridula, wasmanni, donisthorpei, formicarii, inquilina, sardiniae, trichura.
Ripersiella leucosoma.
Termitococcus aster, brevicornis.
Stictococcus formicarii.
Exaeretopus formiceticola.
Lecanium formicarii, urichi, discrepans.
Lecanopsis formicarum, lineolata, myrmecophila.
Houardia troglodytes.
APOLLONIAS (Lauraceae).
Lecanium hesperidum.
Cryptaspidiotus aonidioides, barbusano.
Aspidiotus lauretorum, dictyospermi, camelliae.
Aonidia lauri.
Fiorinia pellucida.
'APPLE'
Pseudococcus bakeri.
Pulvinaria amygdali, innumerabilis.
Lecanium hoferi, bituberculatum, cerasifex, pyri, variegatum, oleae, glandi.
Chionaspis furfura.
Diaspis pyri.
Epidiaspis pyricola.
Aspidiotus ancylus, forbesi, juglans-regiae, ostreaeformis, perniciosus, pyri, camelliae, aurantii, africanus, tenebricosus, lataniae.
Parlatoria calianthina, proteus, de structor, chinensis, pyri.
Leucaspis japonica.
Lepidosaphes ulmi.
'APRICOT.'
Lecanium armeniacum, oleae.
Diaspis pentagona.
Aspidiotus forbesi, juglans-regiae, perniciosus, africanus.
ARALIA (Araliaceae).
Pulvinaria innumerabilis, floccifera, psidii.
Lecanium persicae, hesperidum, oleae, nigrum, persicae-crudum.
Diaspis pentagona.
Aspidiotus ficus, dictyospermi.
ARAUCARIA (Coniferae).
Eriococcus araucariae, angulatus.
Pseudococcus aurilanatus, ryani, adonidum.
Ctenochiton araucariae.
Aspidiotus rossi.
Parlatoria pergandei.
ARBUTUS (Ericaceae).
Lecanium coryli, corni.
Aspidiotus hederae, vitis-arbutus, dictyospermi.
ARCTOSTAPHYLUS (Ericaceae).
Eriococcus uvae-ursi.
Pulvinaria ericae.
Diaspis manzanitae.
Aspidiotus dearnessi, arctostaphyli.
Chionaspis salicis.
Lepidosaphes ulmi.
ARDISIA (Myrsinaceae).
Nipponorthezia ardisiae.
Lecanium hemisphaericum, tessellatum.
Chionaspis acuminata.

ARECA (Palmae).
- Pseudococcus arecae.
- Lecanium minimum, hemisphaericum, 'acutissimum.
- Hemichionaspis aspidistrae, dracaenae.
- Diaspis boisduvallii.
- Pinnaspis buxi.
- Aspidiotus lataniae, dictyospermi, personatus.
- Fiorinia fioriniae.

ARISTOLOCHIA (Aristolochiaceae).
- Icerya aegyptiaca.
- Pseudococcus longispinus.
- Aspidiotus lataniae.

ARMERIA (Plumbagineae).
- Pseudococcus hibernicus.
- Ripersia halophila.

ARTEMISIA (Compositae).
- Orthezia artemisiae, urticae.
- Eriococcus artemisiae, catalinae.
- Phenacoccus artemisiae.
- Pseudococcus artemisiae.
- Erium lichtensioides.
- Pulvinaria artemisiae.
- Ceroplastes rusci.
- Aspidiotus rossi.

ARTOCARPUS (Urticaceae).
- Monophlebus octocaudata.
- Icerya aegyptiaca.
- Pseudococcus corymbatus.
- Lecanium mangiferae, psidii.
- Chionaspis subcorticalis.
- Aspidiotus longispinus, artocarpi, hederae, lataniae, trilobitiformis.
- Fiorinia fioriniae.

ARUNDINARIA (Gramineae).
- Asterolecanium lanceolatum, solenophoroides.
- Antonina socialis.
- Aclerda distorta, japonica.
- Lecanium arundinariae.
- Chionaspis arundinariae, elongata.
- Odonaspis secreta.

ARUNDO (Gramineae).
- Aclerda berlesii.
- Chionaspis berlesii.

ASPARAGUS (Liliaceae).
- Pseudococcus longispinus, virgatus.
- Lecanium anthurii, hemisphaericum, nigrum, oleae.
- Filippia ephedrae.
- Chionaspis berlesii.
- Aspidiotus hederae, cydoniae, camelliae.

ASPIDISTRA (Liliaceae).
- Hemichionaspis aspidistrae.
- Aspidiotus ficus.

ASPLENIUM (Filices).
- Lecanium hesperidum, mori, oleae.
- Hemichionaspis aspidistrae.
- Chionaspis dubia.

ASTELIA (Liliaceae).
- Phenacoccus asteliae.
- Pseudococcus montanus.
- Leucaspis gigas, stricta.
- Lepidosaphes cordylinidis, epiphytidis, pryiformis.

ASTER (Compositae).
- Orthezia urticae.
- Eriococcus eucalypti.
- Tachardia australis.
- Lecanium oleae.

ATALANTIA (Rutaceae).
- Aspidiotus ficus.
- Parlatoria atalantiae.
- Fiorinia atalantiae.

ATHEROSPERMA (Atherospermaceae).
- Lecaniodiaspis atherospermae.
- Eriochiton spinosus.
- Ctenochiton viridis.
- Chionaspis eugeniae.
- Leucaspis gigas.
- Aspidiotus atherospermae.
- Lepidosaphes pyriformis.

ATRIPLEX (Chenopodiaceae).
- Orthezia annae, varipes.
- Cerococcus coloradensis.
- Atriplicia gallicola.
- Eriococcus neglectus, tinsleyi, parcispinosus.
- Phenacoccus simplex.
- Pseudococcus solani-atriplicis.
- Pulvinaria maskelli.
- Ceroplastes irregularis, breviseta.
- Luzulaspis spinulosa.
- Lepidosaphes concolor, concolor-viridissima, alba, alba-concolor.

- ATYLOSIA (Leguminosae).
  - Ceroplastodes cajani.
  - Aspidiotus orientalis.
- AUCUBA (Cornaceae).
  - Chionaspis aucubae.
  - Aspidiotus hederae, dictyospermi, aurantii-citrinus.
- AVERRHOA (Oxalidaceae).
  - Lecanium longulum.
  - Inglisia conchiformis.
- AZALEA (Ericaceae).
  - Eriococcus azaleae.
  - Pseudococcus azaleae.
  - Phenacoccus azaleae.
  - Aspidiotus duplex, paeoniae.

- BACCHARIS (Compositae).
  - Cerococcus baccharidis, tuberculus, badius.
  - Eriococcus armatus, brasiliensis.
  - Ceroplastes albolineatus, grandis, iheringi, lucidus, novaesi.
  - Alichtensia attenuata.
  - Pulvinaria pulchella.
  - Lecanium baccharidis, dura, resinatum.
  - Diaspis baccharidis.
  - Lepidosaphes perlonga.
- BACTRIS (Palmae).
  - Asterolecanium urichi.
  - Diaspis boisduvallii.
- BAHIA (Compositae).
  - Palaeococcus townsendi.
  - Orthezia californica.
  - Ceroputo bahiae.
  - Eriococcus bahiae.
- BAMBUSA (Gramineae).
  - Asterolecanium bambusae, delicatum, miliaris, miliaris-longum, miliaris-robusta, solenophoroides, coronatum, lanceolatum, ceriferum, ceriferum-prominens, exiguum, flavociliatum, pudibundum, rubrocomatum, tenuissimum, tumidum, udagamae, bambusicola, masuii.
  - Eriococcus graminis, onukii.
  - Pseudococcus takae, monticola, pulverarius-bambusae.
  - Antonina bambusae, crawi, socialis, zonata.
  - Pseudantonina bambusae.
  - Aclerda japonica, distorta.
  - Lecanium longulum, depressa, nigrum, arundinariae.
  - Diaspis bambusae.
  - Chionaspis arundinariae, bambusae, colemanni, howardi, elongata, linearis, gudelura, annandalei.
  - Pinnaspis bambusae.
  - Fiorinia bambusae, signata, tenuis.
  - Leucaspis bambusae.
  - Odonaspis bambusarum, canaliculata, inusitata, secreta, simplex, penicillata, schizostachys.
  - Lepidosaphes bambusicola, bambusae.
  - Ischnaspis filiformis.
  - Aspidiotus ficus.
  - Parlatoria zeylanica.
- BANKSIA (Proteaceae).
  - Callipappus bufo.
  - Asterolecanium variolosum.
  - Eriococcus eucalypti.
  - Ceronema banksiae.
  - Lecanium frenchi, fuciforme.
  - Aspidiotus subrubescens, rossi.
  - Aonidia banksiae.
  - Lepidosaphes banksiae, citricola, fulleri, grandilobis.
- BAUHINIA (Leguminosae).
  - Asterolecanium pustulans.
  - Lecanium hesperidum.
- BEAUMONTIA (Apocynaceae).
  - Lecanium beaumontiae.
  - Aspidiotus trilobitiformis.
- BEGONIA (Begoniaceae).
  - Lecanium begoniae, nigrum, hesperidum, signiferum.
  - Aspidiotus ficus.
- BENZOIN (Lauraceae).
  - Lecanium nigrofasciatum.
  - Chionaspis lintneri.
- BERBERIS (Berberidaceae).
  - Fonscolombia braggi.
  - Lecanium magnoliarum, corni, persicae.
  - Epidiaspis leperei.
  - Lepidosaphes ulmi.

- BETULA (Betulaceae) 'Birch.'
  - Xylococcus betulae.
  - Steingelia gorodetskia.
  - Phenacoccus aceris.
  - Pulvinaria vitis, betulae, occidentalis-subalpina.
  - Lecanium douglasi, nigrofasciatum, websteri, coryli, ciliatum, zebrinum, transvittatum.
  - Chionaspis lintneri-betulae, salicis.
  - Aspidiotus ostreaeformis, perniciosus, camelliae.
  - Lepidosaphes ulmi.
- BEYERIA.
  - Apiomorpha beyeriae.
  - Tachardia australis.
  - Lepidosaphes beyeriae.
- BIGELOWIA (Orchidaceae).
  - Pulvinaria bigeloviae.
  - Aspidiotus bigeloviae, yuccarum.
- BIGNONIA (Bignoniaceae).
  - Pulvinaria cupaniae, psidii.
  - Ceroplastes cistudiformis.
  - Lecanium viride.
- BIOTA (Coniferae).
  - Lecanium arion.
  - Diaspis visci.
- BOSSIAEA (Leguminosae).
  - Pulvinaria contexta.
  - Aspidiotus bossieae.
- BOUGAINVILLEA (Nyctagineae).
  - Orthezia insignis.
  - Asterolecanium pustulans-seychellarum.
- BRACHYGLOTTIS (Compositae).
  - Ctenochiton flavus.
  - Fiorinia minima.
- BROUSSONETIA (Urticaceae) 'Paper-Mulberry.'
  - Lecanium corni.
  - Diaspis pentagona.
  - Aspidiotus oreodoxae, longispinus, hederae.
- BURSARIA (Pittosporaceae).
  - Cerococcus auranticus.
  - Eriococcus eucalypti, tepperi, bursariae, villosa.
- BURSERA (Burseraceae).
  - Icerya purchasi.
  - Ceroplastes cassiae, dugesii.
- BUXUS (Euphorbiaceae) 'Box.'
  - Eriococcus buxi.
  - Phenacoccus aceris.
  - Lecanium hesperidum, corni.
  - Pinnaspis buxi.
  - Aspidiotus hederae, aurantii, dictyospermi, britannicus, rossi.

- CACTUS (Cactaceae).
  - Llaveia cacti.
  - Dactylopius cacti, confusus, newsteadi, tomentosus, indicus, argentinus.
  - Eriococcus coccineus, multispinosus.
  - Pseudococcus mamillariae, virgatus.
  - Pulvinaria floccifera.
  - Diaspis echinocacti.
  - Aspidiotus cydoniae.
- CAESALPINIA (Leguminosae).
  - Tachardia lacca.
  - Pseudococcus virgatus.
  - Ceronema africana.
  - Aspidiotus subsimilis.
- CAJANUS (Leguminosae) 'Pigeon-pea.'
  - Tachardia lacca.
  - Phenacoccus insolitus.
  - Stictococcus dimorphus, diversiseta.
  - Lecanium elongatum, oleae, cajani.
  - Ceronema africana.
  - Eriochiton theae.
  - Ceroplastes africanus, ugandae.
  - Ceroplastodes cajani, chiton.
- CALADIUM (Araceae).
  - Pseudococcus longispinus.
  - Pulvinaria darwiniensis.
- CALAMAGROSTIS (Gramineae).
  - Trionymus perrisii.
  - Eriopeltis lichtensteini.
- CALAMUS (Palmaceae).
  - Aspidiotus calami.
  - Lepidosaphes mexicana.
- CALATHEA (Marantaceae).
  - Asterolecanium aureum.
  - Pseudococcus citri.
  - Hemichionaspis aspidistrae.
- CALLICARPA (Verbenaceae).
  - Mallococcus sinensis.
  - Howardia biclavis.
  - Diaspis pentagona.

CALLISTEMON (Myrtaceae).
- Pseudococcus citri.
- Chionaspis candida.
- Aspidiotus dictyospermi, rossi.
- Aonidia pulchra.

CALLITRIS (Coniferae).
- Pulvinaria maskelli-spinosior.
- Diaspis visci.
- Cryptaspidiotus mediterraneus.
- Poliaspis exocarpi.
- Chionaspis striata.

CALLUNA (Ericaceae) 'Ling,' 'Heather,' etc.
- Orthezia cataphracta.
- Eriococcus ericae.
- Pseudococcus calluneti.
- Lecanium pulchrum, franconicum.
- Aspidiotus bavaricus.
- Lepidosaphes ulmi.

CALOPHYLLUM (Guttiferae).
- Asterolecanium gutta, ceÿlonicum.
- Erioides cuneiformis.
- Lecanium bicruciatum, frontalis, calophylli, tessellatum, tripartitum.
- Ceroplastes rubens.
- Aspidiotus dictyospermi, calophylli.

CALOTROPIS (Asclepiadaceae).
- Lecanium oleae.
- Aspidiotus orientalis.

CALYCOTOME (Leguminosae).
- Lecanium persicae.
- Aspidiotus hederae.

CAMELLIA (Ternstromiaceae).
- Lecanium hesperidum, depressum-simulans, hemisphaericum, oleae.
- Pulvinaria camelicola, floccifera, linearis, vitis.
- Ceroplastes ceriferus, floridensis.
- Aspidiotus degeneratus, hederae, camelliae, spinosus, ficus, maskelli, clavigera, duplex, paeoniae, dictyospermi.
- Parlatoria pergandei-camelliae, proteus, proteus-virescens.
- Fiorinia fioriniae.

CAMPANULA (Campanulaceae).
- Asterolecanium fimbriatum.
- Aspidiotus implicatus.

CAMPHORA (Lauraceae).
- Aspidiotus duplex, ficus, aurantii.

CANNA (Marantaceae) 'Indian Shot,' etc.
- Pseudococcus bromeliae.
- Lecanium nigrum.
- Ceroplastes actiniformis, ceriferus.
- Diaspis bromeliae.

CAPPARIS (Capparidaceae).
- Phenacoccus iceryoides.
- Lecanium capparidis.
- Hemichionaspis aspidistrae.
- Aspidiotus rossi, hederae, niger, pseudocamelliae.

CAPSICUM (Solanaceae).
- Orthezia insignis, praelonga.
- Icerya purchasi.
- Pulvinaria urbicola.
- Hemichionaspis minor.

CAREX (Cyperaceae).
- Orthezia cataphracta.
- Exaeretopus caricis.
- Luzulaspis luzulae.
- Lecanopsis longicornis.
- Parafairmairia gracilis.

CARICA (Cucurbitaceae) 'Papaya.'
- Lecanium longulum.
- Diaspis pentagona.
- Aspidiotus orientalis, destructor.

CARISSA (Apocynaceae).
- Cerococcus ornatus.
- Lecanium maritimum, oleae, hemisphaericum, longulum.
- Chionaspis acuminata-atricolor.
- Poliaspis carissae.
- Aonidia pusilla.
- Aspidiotus rossi, lataniae.

CARPINUS (Corylaceae) 'Hornbeam,' etc.
- Phenacoccus acericola, aceris.
- Lecanium alni-rufulum, ribis, websteri, coryli, pulchrum.
- Pulvinaria carpini, betulae.
- Aspidiotus ostreaeformis.
- Lepidosaphes ulmi.

CARYA (Juglandaceae) 'Hickory,' 'Pecan,' etc.
- Pseudococcus jessica.
- Lecaniodiaspis tessellata.
- Lecanium canadense, caryae, caryarum, pyri.
- Chionaspis caryae.

- CARYA (Juglandaceae)—*cont.*
  - Aspidiotus perniciosus, uvae, obscurus.
- CARYOTA (Palmaceae).
  - Lecanium tessellatum, signiferum.
- CASSIA (Leguminosae).
  - Icerya seychellarum.
  - Tachardia lacca.
  - Pseudococcus virgatus.
  - Lecanium longulum, opimum, tuberculatum.
  - Ceroplastes cassiae.
  - Ceroplastodes chiton.
  - Ctenochiton aztecus.
  - Hemichionaspis minor, chionaspiformis.
  - Chionaspis cassiae.
  - Aspidiotus tesseratus, victoriae, orientalis.
- CASSINE (Celastraceae).
  - Chionaspis elongata.
  - Aspidiotus piceus.
- CASTANEA (Corylaceae) 'Spanish Chestnut.'
  - Pseudopulvinaria sikkimensis.
  - Lecanium armeniacum, quercitronis, takachihoi, pulchrum, nigrofasciatum.
  - Aspidiotus perniciosus.
  - Lepidosaphes ulmi.
- CASTILLOA (Artocarpaceae).
  - Pseudococcus virgatus, crotonis.
  - Lecanium castilloae.
  - Inglisia castilloae.
  - Aspidiotus destructor.
- CASUARINA (Casuarinaceae).
  - Callipappus bufo, farinosus.
  - Icerya purchasi.
  - Frenchia casuarinae, semiocculta.
  - Cylindrococcus casuarinae, gracilis, spiniferus.
  - Sphaerococcus casuarinae, ethelae, lesii.
  - Ouracoccus casuarinae.
  - Gossyparia casuarinae.
  - Eriococcus conspersus, cypraeaeformis, elegans.
  - Rhizococcus casuarinae, pustulatus, tripartitus, lecanioides, casuarinaemancus.
  - Pseudoripersia turgipes.
  - Pseudococcus corymbatus.
  - Phenacoccus casuarinae.
  - Lecanium innocens.
  - Poliaspis casuarinae.
  - Fiorinia casuarinae.
  - Aspidiotus casuarinae, eucalypti, cingulatus, pauciglandulatus, bidens.
  - Aonidia paradoxa.
  - Lepidosaphes casuarinae, striata, lobulatus, complicata.
- CATALPA (Bignoniaceae).
  - Ceroplastes marmoreus, mexicanus.
  - Diaspis pentagona.
  - Aspidiotus perniciosus, ulmi.
- CATTLEYA (Orchidaceae).
  - Lecanium pseudohesperidum.
  - Diaspis boisduvallii, cattleyae.
  - Aspidiotus alienus, biformis-cattleyae.
- CEANOTHUS (Rhamnaceae).
  - Ceroputo yuccae, yuccae-ceanothi.
  - Chionaspis salicis-nigrae.
  - Lepidosaphes ulmi.
- CEARA RUBBER (Manihot glaziovii).
  - Lecanium nigrum.
  - Aspidiotus destructor.
- CEDRUS (Coniferae).
  - Aspidiotus perniciosus, cedri, hederae.
- CELTIS (Ulmaceae).
  - Lecaniodiaspis celtidis.
  - Lecanium subaustrale, websteri, celtium.
  - Pulvinaria innumerabilis, tinsleyi, photiniae.
  - Lichtensia colimensis.
  - Pinnaspis siphonodontis.
  - Diaspis celtidis, pentagona.
  - Fiorinia fioriniae
  - Aspidiotus cueroensis, ancylus, celtis.
  - Parlatoria pergandei.
  - Lepidosaphes mexicana, conchiformis.
- CENTAUREA (Compositae).
  - Gueriniella serratulae.
  - Orthezia urticae.

- CERASUS (Rosaceae) 'Cherry,' 'Evergreen Laurel,' etc.
  - Kuwanina parvus.
  - Lecanium elongatum, armeniacum, caryae, cerasi, cerasifex, cerasorum, rugosum, tiliae, capreae.
  - Chionaspis furfura.
  - Diaspis pentagona.
  - Aspidiotus ancylus, forbesi, hederae, juglans-regiae, ostreaeformis, patavinus.
  - Lepidosaphes ulmi.
- CERATONIA (Leguminosae).
  - Gueriniella serratulae.
  - Pseudococcus ceratoniae, citri.
  - Lecanium corni.
  - Chionaspis ceratoniae.
  - Aspidiotus hederae, aurantii, dictyospermi, britannicus.
  - Lepidosaphes ceratoniae, ulmi
- CERCIS (Leguminosae).
  - Lecanium kansasense, nigrofasciatum.
  - Aspidiotus camelliae.
- CEREUS (Cactaceae).
  - Diaspis echinocacti.
  - Aspidiotus eglandulosus, hederae.
- CESTRUM (Solanaceae).
  - Erium zapotlanum.
  - Lecanium nocturnum.
  - Pulvinaria cestri.
- CHAMAECYPARIS (Coniferae) 'White Cedar.'
  - Lecanium pallidior.
  - Diaspis visci.
- CHAMAEROPS (Palmaceae).
  - Colobopyga magnani.
  - Ripersia falcifera.
  - Lecanium hesperidum.
  - Ceroplastes rusci.
  - Aspidiotus chamaeropsis, dictyospermi, hederae.
  - Lepidosaphes pinnaeformis.
- CHENOPODIUM (Chenopodiaceae).
  - Orthezia annae.
  - Aspidiotus chenopodii.
  - Lepidosaphes concolor.
- CHILOPSIS (Bignoniaceae).
  - Lecanium chilaspidis.
  - Aspidiotus coloratus.
  - Lepidosaphes chilopsidis.
- CHLOROPHORA (Moraceae).
  - Lecanium oleae.
  - Diaspis regularis.
- CHRYSANTHEMUM (Compositae).
  - Orthezia insignis.
  - Lecanium oleae.
  - Ceroplastes cistudiformis, rusci.
  - Aspidiotus cydoniae-greeni, canariensis.
- CHRYSOBALANUS (Rosaceae).
  - Tachardia gemmifera.
  - Lecanium pseudotessellatum.
- CHRYSOPHYLLUM (Sapotaceae).
  - Icerya montserratensis.
  - Lecanium hemisphaericum.
  - Howardia biclavis.
  - Aspidiotus fissidens-pluridentatus.
- CINCHONA (Rubiaceae).
  - Pseudopulvinaria sikkimensis.
  - Lecanium viride, hemisphaericum, nigrum.
  - Pulvinaria psidii.
  - Howardia biclavis.
  - Aspidiotus cyanophylli, camelliae.
- CINNAMOMUM (Lauraceae).
  - Lecanium mangiferae, cinnamomi, pseudoleae, tessellatum.
  - Protopulvinaria pyriformis.
  - Ceroplastes rubens.
  - Diaspis tubercularis.
  - Chionaspis cinnamomi, litseae.
  - Aspidiotus articulatus, longispinus, dictyospermi, ficus, cistuloides.
  - Parlatoria cinnamomi.
- CISSUS (Vitaceae).
  - Cissococcus fulleri.
  - Aspidiotus tesseratus.
- CISTUS (Cistaceae).
  - Asterolecanium fimbriatum.
  - Lecaniodiaspis sardoa.
  - Ripersia falcifera.
- CITRUS (Rutaceae) 'Orange,' 'Lemon,' etc.
  - Palaeococcus rosae.
  - Icerya seychellarum, montserratensis, natalensis, purchasi, okadae, aegyptiaca.
  - Orthezia insignis, praelonga.
  - Tachardia aurantiaca.
  - Pseudococcus citri, filamentosus,

CITRUS (Rutaceae)—*cont.*
longispinus, lilacinus, fragilis, virgatus, nipae, bakeri, ryani, citrophilus, citriculus.
Ceroputo yuccae, arctostaphyllii.
Lecanium hesperidum, longulum; perlatum, viride, punctatum, townsendi, quercitronis-kermoides, tiliae, nigrum, hemisphaericum, oleae, pseudomagnoliarum, citricola, perinflatum, andersoni.
Pulvinaria aurantii, innumerabilis, mammeae, psidii, tecta, cellulosa, okitsuensis, citricola, floccifera.
Ceroplastes ceriferus, cirripediformis, floridensis, rubens, sinensis, rusci.
Takahashia citricola.
Chionaspis citri, euonymi, sassceri.
Howardia biclavis.
Hemichionaspis aspidistrae, minor.
Diaspis pentagona.
Dinaspis annae.
Aspidiotus cydoniae, hederae, lataniae, perniciosus, duplex, albopunctatus, camelliae, trilobitiformis, ficus, articulatus, albopictus, albopictus-leonis, aurantii, koebelei, personatus, scutiformis, cocotiphagus, maskelli, dictyospermi, sylvaticus, pedroniformis, orientalis.
Parlatoria pergandei, proteus, sinensis, ziziphus, oleae.
Lepidosaphes citricola, gloveri, pallida.

CLEMATIS (Ranunculaceae).
Pseudococcus capensis.
Lecanium hesperidum, oleae, corni, persicae, nigrofasciatum.
Aspidiotus hederae.
Lepidosaphes ulmi.

CLIFFORTIA (Rosaceae).
Icerya natalensis.
Pseudococcus segnis.

CLUSIA (Guttiferae).
Icerya montserratensis.
Gymnaspis clusiae.

COBAEA (Polemoniaceae).
Lecanium nigrum, hemisphaericum.

COCCOLOBA (Polygonaceae).
Lecanium hesperidum.
Ceroplastes dugesii.
Aspidiotus rossi.

COCCULUS (Menispermaceae).
Icerya seychellarum.
Lepidosaphes cocculi.

COCOS (Palmaceae) 'Coconut Palm.'
Icerya montserratensis.
Asterolecanium palmae, lineare.
Pseudococcus cocotis, pseudonipae, virgatus, citri, nipae.
Lecanium acutissimum, hemisphaericum, tessellatum.
Paralecanium cocophyllae.
Ceroplastes actiniformis.
Vinsonia stellifera.
Chionaspis inday, candida.
Hemichionaspis aspidistrae, minor.
Pinnaspis buxi-alba.
Diaspis boisduvallii-cocois, vandalicus.
Aspidiotus cydoniae, lataniae, palmae, destructor, ficus, aurantii, perseae, oceanica, cocotiphagus, ansei, propsimus, varians, orientalis, punicae, personatus, articulatus.
Cryptaspidus nucum.
Parlatoria greeni.
Fiorinia fioriniae.
Lepidosaphes macgregori, unicolor, gloveri.

CODIAEUM (Euphorbiaceae).
Pseudococcus crotonis, virgatus.
Lecanium nigrum, longulum, cribrigerum.
Pulvinaria thespesiae.
Aspidiotus destructor.
Cryptophyllaspis rubsaameni.
Parlatoria proteus.
Lepidosaphes newsteadi-tokionis, pinnaeformis, auriculata.

COFFEA (Rubiaceae).
Ortheziola fodiens.
Asterolecanium coffeae.
Cerococcus ornatus.
Stictococcus sjostedti, gowdeyi.
Pseudococcus citri, coffeae, filamentosus, virgatus.

- COFFEA (Rubiaceae)—*cont.*
  - Lachnodius greeni.
  - Rhizaecus eloti.
  - Lecanium caudatum, viride, hemisphaericum, nigrum, oleae, hesperidum-javanensis, africanum, subhemisphericum.
  - Howardia biclavis.
  - Aspidiotus articulatus.
  - Ischnaspis longirostris.
  - Lepidosaphes corrugata.
- COLA (Sterculiaceae) 'Kola-nut.'
  - Stictococcus sjostedti, multispinosus, bijubatus.
  - Lecanium catori.
- COLEUS (Labiatae).
  - Orthezia insignis.
  - Pseudococcus citri-coleorum.
  - Ceroputo barberi.
  - Lecanium depressum.
- CONVOLVULUS (Convolvulaceae).
  - Pseudococcus virgatus.
  - Ripersia falcifera.
  - Lecanium hesperidum, oleae.
  - Ceroplastes rusci.
- COPROSMA (Rubiaceae).
  - Pseudococcus glaucus.
  - Ctenochiton depressus-minor, perforatus, viridis.
  - Inglisia patella.
  - Chionaspis dubia.
  - Leucaspis gigas.
  - Poliaspis argentosus.
  - Aspidiotus camelliae.
  - Lepidosaphes pyriformis.
- CORDIA (Boraginaceae).
  - Orthezia galapagoensis.
  - Lecanium mangiferae.
  - Pulvinaria floccifera.
  - Protopulvinaria pyriformis.
  - Diaspis cordiae.
- CORDYLINE (Liliaceae).
  - Pseudococcus calceolariae.
  - Leucaspis cordylinidis, stricta.
  - Aspidiotus articulatus, dictyospermi, hederae, cyanophylli.
  - Lepidosaphes cordylinidis.
- CORNUS (Cornaceae) 'Dog-wood,' etc.
  - Phenacoccus aceris.
  - Lecanium corni, tarsale, coryli.
  - Chionaspis corni, lintneri, salicis, salicis-nigrae.
  - Aspidiotus perniciosus.
  - Lepidosaphes ulmi.
- COROKIA.
  - Cerococcus corokiae.
  - Inglisia inconspicua.
  - Aspidiotus corokiae.
- CORONILLA (Leguminosae).
  - Orthezia urticae.
  - Asterolecanium fimbriatum.
  - Aspidiotus hederae.
- CORREA (Rutaceae).
  - Sphaerococcus floccosus.
  - Lecanium hesperidum.
  - Aspidiotus dictyospermi.
- CORYLUS (Corylaceae) 'Hazel,' etc.
  - Gossyparia spuria.
  - Phenacoccus aceris.
  - Lecanium corni, corylis, corylifex, betulae, pulchrum.
  - Aspidiotus ostreaeformis.
  - Lepidosaphes ulmi.
- CORYNEPHORUS (Gramineae).
  - Ripersia corynephori.
  - Eriopeltis festucae.
- CORYNOCARPUS (Myrsinaceae).
  - Icerya purchasi.
  - Diaspis monserrati.
  - Aspidiotus hederae.
- COTONEASTER (Rosaceae).
  - Lecanium coryli, corni, persicae.
  - Pulvinaria betulae.
  - Aspidiotus perniciosus.
  - Lepidosaphes ulmi.
- COURSETIA.
  - Icerya palmeri.
  - Tachardia fulgens.
  - Aspidiotus coursetiae.
- CRATAEGUS (Rosaceae) 'Hawthorn,' 'White-thorn,' etc.
  - Eriococcus azaleae, dearnessi.
  - Phenacoccus dearnessi.
  - Cerococcus koebelei.
  - Lecanium bituberculatum, genevense, pyri, nigrofasciatum.
  - Pulvinaria innumerabilis, occidentalis, oxyacanthae.
  - Chionaspis furfurus.

- CRATAEGUS (Rosaceae)—*cont.*
  - Aspidiotus forbesi, ostreaeformis, perniciosus, calurus.
  - Lepidosaphes ulmi, ulmi-candida.
- CROTALARIA (Leguminosae).
  - Diaspis pentagona.
  - Hemichionaspis minor.
- CROTON (Euphorbiaceae).
  - Icerya aegyptiaca, braziliensis, montserratensis, caudatum, seychellarum.
  - Orthezia praelonga, insignis.
  - Tachardia albizziae, rubra, lacca.
  - Pseudococcus longispinus, virgatus, capensis.
  - Ceroputo barberi.
  - Stictococcus dimorphus, diversiseta.
  - Lecanium hemisphaericum, nigrum.
  - Pulvinaria burkilli.
  - Ceroplastes denudatus, ceriferus.
  - Lichtensia lutea.
  - Aspidiotus dictyospermi, smilacis.
  - Parlatoria crotonis.
  - Lepidosaphes citricola, crotonis, lasianthi, pinnaeformis, auriculata, serrifrons.
- CRUDIA.
  - Aonidia biafrae.
  - Lepidosaphes crudiae.
- CRYPTOMERIA (Coniferae).
  - Diaspis visci.
  - Aspidiotus cryptomeriae.
- CUPANIA (Sapindaceae).
  - Pulvinaria cupaniae.
  - Aspidiotus longispinus.
- CUPRESSUS (Coniferae) 'Cypress.'
  - Icerya purchasi.
  - Gueriniella serratulae.
  - Phenacoleachia zealandica.
  - Xylococcus macrocarpae.
  - Sphaerococcus cupressi.
  - Pseudococcus ryani, andersoni, dudleyi, cupressi.
  - Diaspis visci.
  - Chionaspis striata.
  - Fiorinia fioriniae.
  - Leucaspis cupressi.
  - Aspidiotus cupressi, coniferarum-shastae.
- CYANOPHYLLUM (Melastomaceae).
  - Lecanium oleae.
  - Aspidiotus cyanophylli.
- CYANOTIS (Commelinaceae).
  - Hemichionaspis aspidistrae.
  - Aspidiotus excisus.
- CYATHODES (Epacridaceae).
  - Eriococcus multispinus.
  - Poliaspis media.
- CYCAS (Cycadaceae).
  - Pseudococcus longispinus, zamiae.
  - Lecanium hesperidum, hemisphaericum, palmae, oleae, acutissimum.
  - Ceroplastes myricae, rubens.
  - Diaspis zamiae, rosae.
  - Hemichionaspis minor.
  - Poliaspis cycadis.
  - Fiorinia fioriniae.
  - Aspidiotus cyanophylli, hederae, ulmi, dictyospermi, aurantii, ficus, articulatus, rossi, lataniae, orientalis, fimbriatus-capensis.
  - Parlatoria proteus.
- CYDONIA (Rosaceae).
  - Tachardia cydoniae, rubra, angulata.
  - Phenacoccus suwakoensis, aceris.
  - Lecanium rugosum, coryli, corni, nigrofasciatum.
  - Pulvinaria betulae.
  - Ceroplastes cirripediformis, floridensis.
  - Chionaspis furfura.
  - Aspidiotus ancylus, cydoniae, forbesi, perniciosus, camelliae, aurantii, africanus, ostreaeformis.
  - Lepidosaphes ulmi.
- CYNODON (Gramineae).
  - Monophlebus fulleri.
  - Margarodes mediterraneus.
  - Eriococcus formicicola.
- CYNOMETRA (Leguminosae).
  - Diaspis limuloides.
  - Aonidia biafrae.
  - Lepidosaphes aberrans, tenuior.
- CYPERUS (Cyperaceae).
  - Newsteadia floccosa.
  - Antonina australis, maritima.
  - Pseudococcus sexaspinus.
  - Lecanium angustatum.

CYPERUS (Cyperaceae)—*cont.*
  ASPIDIOTUS cladii.
CYPRIPEDIUM (Orchidaceae).
  ASTEROLECANIUM aureum.
  ASPIDIOTUS dictyospermi.
CYTISUS (Leguminosae).
  PSEUDOCOCCUS aridorum.
  PHENACOCCUS ulicis.
  LECANIUM distinguendam, corni, hesperidum.
  CHIONASPIS salicis, canariensis, berlesii.
  LEUCASPIS japonica.
  ASPIDIOTUS camelliae, tasmaniae, hederae.
  LEPIDOSAPHES ulmi.

(*To be continued.*)

NOTE ON THE IMMUNITY OF CHALCID PARASITES TO HYDROCYANIC ACID GAS.

By E. ERNEST GREEN.

Wishing to kill a few individuals of a species of *Lecanium*, for preservation as cabinet specimens, I subjected them to the fumes of strong hydrocyanic acid gas (in an ordinary cyanide bottle) for a period of eighteen hours. In spite of this drastic treatment, large numbers of living Chalcids emerged from the bodies of the Coccids after their removal from the killing-bottle.

This immunity of internal parasites may have a bearing upon the treatment of 'Scale Insects' in the field, when they are known to be infested by useful parasites. It would now appear to be possible to fumigate scale-infested trees, with a fair probability that any Chalcid parasites that may be developing within the bodies of the Coccids will escape—to carry on their useful work elsewhere.

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ON THE LARVAL AND PUPAL STAGES OF *BIBIO JOHANNIS* L.

BY HUBERT M. MORRIS, M.Sc. (MANCH.).

(*From the Department of Agricultural Entomology, Manchester University.*)

(With Plate II and 12 Text-figures.)

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1. INTRODUCTION AND HISTORICAL REMARKS.

During the early part of 1917 I found in the soil of a permanent pasture field at Holmes Chapel, Cheshire, a number of what appeared to be Dipterous larvae of the family Bibionidae, and Dr A. D. Imms suggested to me that a study of these larvae would form a very interesting piece of work.

Some of these larvae were reared and on emergence the fly proved to be *Bibio Johannis* L., for the confirmation of the identity of which I have to thank Mr H. Bury. To Dr Imms I desire to express my thanks for his assistance in many ways during the whole course of the investigation. The work has been carried out in the Department of Agricultural Entomology, Manchester University.

Hitherto there has been no complete account of any Bibionid larva, but only partial descriptions and fragmentary accounts of the life-history.

On account of the frequent occurrence of larvae of this family, and their possible economic importance in certain cases, I have been led to investigate the present species as fully as possible.

The earliest description of the larva and pupa of any species of *Bibio* met with, is that given by Reaumur (1741). Reaumur describes and gives figures of the larva and pupa of the "St. Mark's Fly" (*Bibio Marci*), but, as with all other figures of larvae and pupae of this genus seen, the figures are not sufficiently clear for purposes of identification of species. De Geer (1776) gave the first account and figures of *Bibio Johannis* and in 1832 Lyonet gave a description of *Bibio Marci*. Bouché in 1834 described and figured the larva and pupa of *Bibio hortulanus*, and also figured the mouth parts of the larva, but these figures again are very indefinite. Westwood in 1840 referred briefly to the larva of this genus and gave a small figure. In 1872 Beling described the larvae and pupae of a number of species of *Bibio* and *Dilophus*, amongst others those of *Bibio Johannis*. Needham in 1902 gave an account of the occurrence of swarms of the larvae of *Bibio fraternus*, with descriptions and figures of the larva and pupa, while Sharp (23) has figured a larva of an unnamed species of *Bibio*, and has also given a figure of a portion of the integument of the larva.

In addition to these accounts there are several records of the finding of larvae of different species of *Bibio* in great numbers in a small area (13) and references to damage done by them to cultivated plants. The larvae of the different species of *Bibio* appear to be very similar, which makes identification of the larvae difficult.

2. THE EGG.

The egg (Text-fig. 8, p. 112) is ·63 to ·66 mm. long and ·13 to ·15 mm. broad. It is cylindrical with rounded extremities, and is approximately straight. The eggs are not shiny but have rather an opalescent appearance owing to their being covered with small pointed projections. They are at first of a uniform light straw colour but after a few days a darker patch appears at each end.

3. MORPHOLOGY OF THE LARVA.

(*a*) Newly hatched larva.

The eggs hatched under laboratory conditions in forty-eight days, on May 30th, which appears to be an exceptionally long period. The newly hatched larva is from 1·3 to 1·5 mm. in total length, of which the head measures about ·18 mm., with a breadth of ·16 to ·19 mm. The head is relatively large, yellow brown in colour, and bears a number of long setae.

The body is almost colourless, the contents of the alimentary canal showing through as a broad dark line. In shape it is cylindrical, but it is slightly curved, as in the adult. The body is divided into twelve segments, of which the first is the largest. Each segment bears a number of long slender setae, the length of which varies on different parts of the segment.

Between the long setae on each segment are a number of smaller projections on the cuticle, which correspond to the scale-like structures of older larvae. These projections each consist of a blunt conical base, bearing a single pointed seta, which is directed obliquely backwards. Of the long setae those on the sides are the longest, except on the last and penultimate segments, on which segments those setae situated dorsally are the longest. Each of the long setae arises from a base similar to, but larger than, those of the small setae (Text-fig. 11, p. 112).

The young larva bears a single pair of spiracles, which are situated on the last segment in a corresponding position to that occupied by the spiracles of this segment in the fully grown larva. At the present stage each spiracle has only a single opening.

The structure of the spiracles is similar to that of the spiracles on segments three to ten of the adult larva, but they project very little from the body.

From the extremity of the last segment the larva is able to protrude a pair of membranous conical structures, one on either side of the anus. These structures are protruded by blood pressure, and withdrawn by means of special muscles attached to them. They assist the larva in its movements in a similar manner to the pseudopodia of other larvae.

The head at this stage is very similar to that of the full-grown larva. The antennae, maxillae and labrum show very slight differences from the adult form. The mandibles are shorter at this stage, and their teeth are relatively longer. The groups of setae on the mandibles are present, but they are not so well developed as in the full-grown larva, the setae being shorter and fewer in number.

In the labium, the submentum is rather less stout than that of the full-grown larva, the anterior projections are longer and sharper, while between them is a third projection.

Alimentary Canal. The alimentary canal of the young larva is similar to that of the adult larva. The caeca are rather wider in proportion to their length, and are filled with a yellow fluid. The peritrophic membrane is present as a straight delicate tube lying inside the mesenteron, and extending from its anterior end to about the point at which the posterior caecum opens into the digestive system. The Malpighian tubes are similar to those of the fully grown larva, entering the alimentary canal by a common duct, but the tubes are not enlarged at their point of union. They are colourless, but contain numerous light yellow granules.

Tracheal System. From each spiracle of the pair on the last segment a single short trunk passes inwards, dividing into two on entering the body. One of these branches passes forwards laterally, giving off a fine transverse branch in each segment which connects with the main lateral trunk of the other side; in each segment, except the second and eleventh, a short branch is given off which passes outwards to the cuticle, but has no opening to the outside (Text-fig. 12, p. 114).

From the transverse connective in the first segment, and from the main lateral trunks, a number of branches enter the head and are distributed there.

From the lateral trunks in the eleventh and twelfth segments and from the transverse connective in the twelfth segment a number of fine branches are given off which pass to the heart.

The second of the two branches (into which the trunk from the spiracle divides on entering the body) again divides into a number of finer branches. Most of these branches are distributed in the twelfth segment, but one branch passes forwards, and divides into two at the end of the eleventh segment. The finer of these branches passes to the loop in the alimentary canal, while the other passes forwards into the head outside the main longitudinal trunk. This lateral trunk connects with the branch which passes outwards from the main trunk in each segment, except the second and eleventh.

Circulatory System. The heart lies in segment eleven and in the anterior part of segment twelve; it is continued forward as a dorsal vessel of slightly narrower calibre, to the anterior end of the body.

The heart has a small posterior chamber, provided with a pair of lateral openings by means of which the blood enters. These openings are closed by means of valves when the heart contracts, thus forcing the blood along the dorsal vessel. The latter is very thin walled, the nuclei of the cells of which it is composed bulging inwards into the vessel. The blood is a colourless fluid containing relatively large colourless corpuscles which are usually oval in shape.

Nervous System. The nervous system is similar to that of the full-grown larva. The supraoesophageal ganglion lies in the front of the first segment with the suboesophageal ganglion beneath it. The first thoracic ganglion lies in the posterior region of the first segment, the second is similarly situated in the second segment, while the third ganglion lies rather more forward in the third segment. The eight abdominal ganglia lie in the posterior half of their segments, except the eighth, which is in the front of the eleventh segment.

(*b*) SECOND STAGE LARVA.

The larvae passed into the second stage after nineteen days, under laboratory conditions.

This larva is much more like the full-grown larva in external appearance than is the newly hatched form.

The head does not appear relatively so large, while the long setae on the body have disappeared, the body now bearing processes similar to those of the fully grown larva. The cuticle also bears scale-like structures similar to those of the full-grown larva, but somewhat smaller. The spiracles on the last segment are larger but each has still only a single opening. A smaller pair of spiracles is situated on the first segment as in the full-grown larva, and there is also a still smaller pair of spiracles on the tenth segment. From this latter pair of spiracles the outwardly directed branches from the main longitudinal trunks in that segment take their origin. The tracheal system is similar to that of the first stage larva, but it has more numerous branches.

The mouthparts are very little different from those of the first stage larva, but are slightly more like those of the full-grown larva.

(*c*) FULLY GROWN LARVA.

(*a*) *External Form.* The larva is 10 to 11 mm. long by 1·2 to 1·3 mm. wide and its thickness is a little less than its width. Of this length about ·9 mm. is the length of the head, which is of slightly less width than length. The larva is clearly divided into two distinct regions, (i) The *Head* and (ii) The *Body*.

The *Head* is very clearly defined and is invested by a shining chestnut-brown chitinous capsule which is darker and stronger than the covering of the body. The head can be slightly retracted, so that the posterior end is covered by the front of the first segment of the body. It is darker in the anterior half and on that half bears a few long single setae, while the posterior half, which is lighter, is bare. From the centre of the hind edge of the head arises a fine dark line which passes forwards and almost immediately divides into two, which curve outwards to the bases of the mandibles (Plate II, fig. 5).

The paired appendages of the head are the antennae, mandibles and the first maxillae. Between and below the maxillae there lies a rather peculiar shaped plate. This structure probably represents the second maxillae fused to form a single organ. This plate has another rather crescent shaped plate lying above it. A similar structure often occurs in Dipterous larvae. The lower plate is regarded by Miall and Hammond (17) as the sub-mentum, while the upper plate is regarded as the mentum, which, they consider, has gradually slipped behind the sub-mentum.

The sub-mentum is dark and strongly chitinised, with a central lighter area bearing a group of short setae (Text-fig. 7, p. 112).

There does not appear to be any indication of eyes, and the antennae (Text-fig. 6, p. 112) are small and inconspicuous. The mandibles (Text-fig. 4, p. 111) are large, strong and dark, and have each two large teeth and two smaller ones. They bear on their inner side a prominent group of fine setae some of which are slightly branched.

The maxillae (Text-fig. 5, p. 111) are stout and have a distinct palp. The tops of both palp and maxilla bear a number of setae.

The *Body* is nearly cylindrical, but is slightly flattened dorso-ventrally and normally is curved slightly, the ventral surface forming the inside of the curve. The body consists of twelve segments, of which the first is the longest and has rather the appearance of two segments, but the imaginal discs prove it to be a single segment.

The body bears ten pairs of spiracles which are brown in colour and are situated, a pair on each segment, on all segments except the second and eleventh. The spiracles are situated laterally except those on the twelfth segment which are placed more dorsally than the others. The spiracle on the first segment (Text-fig. 1, p. 110) is about twice the size of those on the third to tenth segments, and that on the twelfth segment is about four times the size of those on the third to tenth segments (Text-figs. 2 and 3, p. 110).

The first segment (Plate II, fig. 1) is divided dorsally into two slightly raised areas, of approximately equal size, by a transverse groove. On the first of these areas are six processes, arranged in a transverse row, those towards the sides being about twice as long as those in the centre. The ventral side is similarly divided into three areas, of which the second is below the first dorsal area, but is curved back in front, and a smaller, roughly triangular, area is formed in front of it, on which are two short processes. On the second area are two short processes in the centre, one about four times as long on each side, and one on each side of intermediate length between those at the sides and those in the middle. On the third raised area are six processes of which the longest, at the sides, are as long as the intermediate ones on the second area. The spiracle on this segment is situated laterally and slightly farther back than the second row of spines on the dorsal side, and projects from the side a distance equal to its own diameter.

The second segment is divided dorsally into three areas in the same manner as the first segment. Of these areas the first bears a process on each side, and the second a row of six processes. Ventrally the same division is visible, the first area bearing two central processes, and the second a row of six processes.

The third segment is similar to the second, but bears a pair of spiracles laterally on the front part of the first raised area.

The fourth segment is also divided into three areas, and bears on the front of each side of the first raised area a spiracle, and on the middle area a transverse row of six processes. Ventrally, it has a row of six processes on the first area, and another row of six processes on the second; the two lateral processes of the latter row appearing behind and a little below the spiracle.

The fifth to tenth segments are similar to the fourth.

On the eleventh segment the row of six dorsal processes are much enlarged; of these, the middle pair are the largest and the lateral ones one-third the size. About the middle of the ventral side of this segment is a row of six processes similar to those on the preceding segments. There is also a lateral process on each side half-way between the dorsal processes and the front edge of the segment (Plate II, fig. 4).

The four processes on the dorsal side of the twelfth segment are also much enlarged, and are situated on the hind margin of the segment. There is, furthermore, a short process on the middle of the side of the ventral surface. The spiracles of the twelfth segment are situated halfway between the lateral processes of the dorsal row, and the front of the segment, and they project twice as much as the preceding spiracles (Plate II, fig. 4). These spiracles have each two openings, while the other spiracles have only one.

The body is covered by a tough cuticle which is actually of a light brown colour, but the larva appears darker owing to particles of soil adhering to it, and to the dark contents of the alimentary canal. The cuticle bears small irregular shaped scale-like structures, which do not touch one another. These structures are of various sizes, and the larger ones are rather conical and bear from one to eight short and usually backwardly directed spines (Plate II, figs. 7 and 8). On the bases of the processes, and on the spiracles of the larva, these structures are closer together and give a more scale-like appearance, while on the processes the spines become considerably longer than elsewhere.

Each intersegmental region bears a row of depressions which vary considerably in shape. They are placed side by side (Plate II, fig. 6) and apparently similar structures are situated, often singly, on other parts of the segments. These depressions are of a darker colour than other parts of the cuticle, and are surrounded by elongated spineless scale-like structures.

On the twelfth segment the scale-like structures form a closer covering, which has rather the appearance of a squamous epithelium. The spines of the scale-like structures on the dorsal surface of this segment are very much reduced or absent, except on the processes, while on the ventral surface a single stouter spine is present on each scale.

From the end of the twelfth segment the larva can protrude pseudopodium-like structures similar to those of the newly hatched larva, but at this stage they are relatively smaller.

(*b*) *Internal structure.* The *Integument* consists of a chitinous cuticle, with the hypodermis or chitogenous layer underlying it.

The *Cuticle* consists of two layers, of which the outer is considerably the thinner, is of a light yellow colour in sections, and is highly refractive, except in the head, where the outer layer is of greater thickness than elsewhere, and is of a brownish yellow colour in sections. The inner layer, which is relatively thick, appears to be only partially chitinised and is more readily stainable than the outer.

The *Hypodermis* appears to be an undifferentiated stratum of protoplasm containing scattered oval nuclei which are hard to distinguish, no cell wall being distinguishable. Below the hypodermis and in contact with its inner surface, is a layer of flattened, irregular-sized cells. Miall and Hammond (17) consider that these are the "Wandering cells." In this larva this sub-hypodermal layer of cells appears to be continuous. The scales consist of a thin stratum of the outer layer of cuticle, which is not continuous beneath them, the interior of the scale being occupied by cuticle of the inner layer. The hypodermis does not enter the scales although it bulges outwards slightly towards their bases. The processes are of similar structure, the hypodermis bulging upwards barely to the base.

The Digestive System.

The alimentary canal takes a nearly straight course through the body from the front of the head to the end of the last segment, but it is slightly longer than the body. It is divided into Fore-Gut, Mesenteron or Mid-Gut, and Hind-Gut, and is provided with salivary glands, caeca and Malpighian tubes (Text-fig. 9, p. 113).

The *Fore-Gut* extends from the mouth to the end of the first segment of the body.

The *mouth* is formed by the labrum above, the mandibles at the sides and the labium and maxillae below. The inner surface of the labrum (the epipharynx) bears numerous short setae, the arrangement of which is shown in Text-fig. 6, p. 112. Some of these setae are probably sensory while others may assist in holding and cutting the food.

The mandibles are mostly used in taking the food into the mouth, and are moved in the same, or almost the same plane, but their shape causes the food between them to be worked against the epipharynx, which bulges slightly downwards. Just behind the mouth the fore-gut dilates slightly into the *pharynx*, from the walls of which muscles radiate to the walls of the head, and circular muscle fibres are present in its walls.

The *Oesophagus* (Text-fig. 9) is a straight and narrow tube of simple structure. It is lined by a chitinous intima, which is considerably folded. Outside the intima, is an epithelium in which the nuclei can be seen but not the cell walls. Outside the epithelium lies a muscular coat, consisting of a layer of circular fibres, forming a series of transverse rings. On the outside of the muscular coat is a thin membrane of connective tissue. Towards the middle of the first segment of the body the oesophagus dilates slightly, and the intima here becomes stronger and has the appearance of small groups of teeth. Behind this is a short region or *Gizzard* with very strongly developed circular muscles and of smaller diameter (Text-fig. 9). The oesophagus ultimately joins the cardia or first portion of the mesenteron, at the end of the first segment.

The *Salivary Glands.* The salivary glands are rather small, and lie one on either side of the alimentary canal, towards the end of the first segment. Each gland is hollow and has a lining of protoplasm. Strands of protoplasm also stretch across the interior of the gland forming a complicated network in which, as well as in the lining of the gland, are large nuclei. The salivary duct passes forwards ventrally from the anterior end of each gland.

The oesophagus is continued a short distance into the cardia, and is then sharply turned back and passes upwards again to the point where the epithelium of the cardia begins, forming an *oesophageal valve.* The part of the oesophagus forming the valve is very similar in structure to that of other parts as far as the first bend. It consists of intima, epithelium, and well-developed circular muscle fibres. The part of the oesophagus between the two bends is composed of an epithelium of much larger cells than the other part, without the muscle fibres. The space between these two parts forms a blood sinus, and is crossed by bands of connective tissue fibres, and there are also bands of longitudinal muscle fibres between the two portions of the oesophagus.

The part of the cardia which follows the oesophagus, and surrounds the valve, consists of deeply staining columnar cells, followed by less deeply staining cells, and this tissue makes several folds into the cardia. These folds chiefly involve the epithelium, but also the moderately developed coat of circular muscle fibres to a small extent. From the anterior part of the cardia a number of bands of muscle fibres stretch to the walls of the oesophagus, without resting on the alimentary canal throughout their length.

From the cardia the three large *caeca* take origin; the longest, which lies parallel to the mesenteron and ventral to it, is about 2·5 mm. long. The other two, which are of about equal length (1·3 to 1·4 mm.), open laterally from the cardia and are slightly inclined upwards.

The caeca are composed of an epithelium similar to that of the mesenteron, the cells of which are rather larger and project slightly into the lumen. Outside the epithelium is a membrane of connective tissue, but no muscle fibres. The caeca are filled with a finely granular substance.

The *Stomach* which follows the cardia has walls of the following structure, from within outwards:

1. The peritrophic membrane, which forms a thin-walled tube lying loose within the stomach from the cardia to near the end of the stomach.

2. The epithelial layer is composed of cells with rather large and dark-staining nuclei, and in some parts a distinct "striated margin" was seen.

3. The basement membrane, outside which is—

4. The muscular coat consisting of poorly developed bands of circular and longitudinal muscle fibres.

5. The connective tissue, which lies outside the muscular coat.

The thickness of the epithelium varies slightly in different parts of the stomach, and it gives off protrusions into the cavity which are finely granular, and feebly staining.

From near the posterior end of the stomach a fourth caecum opens on the ventral side. This caecum is smaller than the others and lies parallel to the stomach with its closed end forwards. Its walls are of a similar structure to those of the other caeca, but are considerably folded near the attached end. The cells of all four caeca show a well-marked "striated margin."

The *Hind-Gut* commences in the ninth segment, but its length is considerably increased by the formation of a loop. It is divided into three parts, the *ileum*, *colon* and *rectum* (Text-fig. 9).

The *Ileum* commences as a slight dilation, and is lined with a layer of epithelium composed of rather large cells, slightly rounded on the inside, and bounded by a fine intima. The epithelium rests on a basement membrane, outside which is a strongly developed coat of circular muscle fibres outside which again are longitudinal muscle fibres, the whole being covered by a thin connective tissue membrane. The circular muscles are very close together, each band touching those next to it. At the commencement of the ileum the circular muscles are particularly well developed.

The *Malpighian tubes* are four in number, and at their attached end they are dilated for a short distance to about twice the diameter of the remainder of their length.

The four dilated ends join together and join the anterior end of the ileum by a short common duct, which lies on the left of the alimentary canal.

The tubes are covered on the outside with a delicate membrane, inside which is a lining of protoplasm containing numerous large nuclei which bulge into the cavity of the tube. The nuclei of the dilated part are smaller than the others but more numerous. The protoplasm contains many fine granules.

The *Colon*, which follows the ileum, is of rather larger diameter, and is less muscular than the ileum. It has a fine intima, outside which is a layer of epithelium rather thinner than that of the ileum. The colon is invested with circular muscle fibres similar to those of the ileum, but they are neither so large nor so close together. Externally the colon is covered with a delicate connective tissue membrane.

The *Rectum* is of considerably smaller diameter than the colon. Its epithelium and intima are deeply folded, filling up much of the gut. The muscular coat is well developed and composed of circular muscles, with a connective tissue membrane outside them.

The *Nervous System.* The nervous system of the *Bibio Johannis* larva consists of a brain or supraoesophageal ganglion, a suboesophageal, three thoracic and eight abdominal ganglia. The brain is two-lobed and lies in the anterior part of the first segment of the body. The two lobes are distinct but are closely connected.

The suboesophageal ganglion lies directly below the brain, and is connected with it by short but fairly fine oesophageal connectives, which connect its anterior end with the anterior end of the lobes of the brain. The head is almost entirely filled with the muscles of the mouthparts, so that the brain is displaced into the first segment. In this latter region, in larvae near pupation, the rudiments of the adult head may be also found.

The first thoracic ganglion lies just behind the suboesophageal, and is nearly as large, the second is close behind it while the third is farther back. The first ganglion is situated at the posterior end of the first segment, the second lies in the front of the second segment and the third in the front of the third segment.

The abdominal ganglia are smaller, and are situated one in each segment. The first seven ganglia lie in the anterior region of their respective segments. The last abdominal ganglion is considerably larger than the others, and is situated toward the hinder region of the eleventh segment.

In the head is a small frontal ganglion which is connected with the brain.

The connectives between the ganglia are clearly double throughout.

From the ganglia lateral nerves are given off, the distribution of which was not studied.

The Tracheal System[1].

From each spiracle except those on the last segment a single tracheal trunk passes inwards, and on passing through the integument it divides into three branches. One branch at once divides into a number of fine branches while the other branches connect with the spiracles before and behind, these connectives also giving off fine branches to the tissues.

From each of the openings of the last pair of spiracles a single trunk passes inwards, and each one then divides into two branches.

4. HABITS, FOOD, ETC.

The larvae of *Bibio Johannis* were found near the surface of the soil, amongst the roots of the grasses of the pasture. The soil near the surface was very rich in organic matter in all stages of decomposition, as the field had been pasture for a number of years. The soil was a medium loam on the surface, but becoming heavier a few inches down.

The larvae were usually found at a depth of not more than half an inch below the surface, and some appeared to be actually on the surface of the soil; they were usually in small colonies, in which the larvae were very close together.

The larvae fed by working particles of soil and organic matter into the mouth by the rather slow movement of the mandibles.

From examinations made of the contents of the alimentary canal it appeared that these larvae had been feeding on decaying vegetable matter only, as only such material and inorganic particles were found.

Several observers record having found the larvae of species of *Bibio* in cow-dung, horse-dung (8, 15) and in other situations where there has been a very high proportion of decaying vegetable matter, as in garden soil (26) and at the base of decaying tree stumps (19). It appears also that larvae of this genus can feed on the roots of living plants.

The larvae of *Bibio Johannis* are moderately active and are able to bury themselves in loose soil fairly quickly, assisted probably by their backwardly directed processes.

The larvae and pupae, contrary to the experience of Malloch (15) were not found difficult to rear. They were reared in medium sized glass jars, partially filled with soil, grass, etc., similar to that amongst which the larvae were found, the jars being covered with coarse muslin and the soil kept damp. As it was desired to obtain the fly rather early in the year, the larvae were kept under cover in a temperature which was always above that outside.

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[1] The spiracles have already been described on pp. 96–98.

Although the larvae were found during the latter half of an unusually severe winter, they appeared but little affected by the cold and did not descend into the soil to any distance as far as was observed.

No parasites were met with in connection with these larvae, and the only reference to parasites met with in this family, is that of Malloch (15). This observer mentions a hymenopterous parasite of whose connection with this family of hosts he is uncertain. Lyonet mentions finding a "louse" on a *Bibionid* larva, and a *Filaria* inside one.

5. COMPARISON WITH LARVAE OF OTHER DIPTERA.

The structure of the larva of *Bibio Johannis* indicates that it is very primitive, the larva having twelve complete segments, a comparatively large head that cannot be withdrawn into the first segment, and well-developed mouthparts.

The presence of ten pairs of spiracles is very unusual, and is characteristic of the family. The fact that the spiracles of the first and twelfth segments are considerably larger than those of the other segments seems to indicate a tendency for the larva to become amphipneustic instead of peripneustic. Of the mouthparts, the most noteworthy is the labium, which is modified in a similar way to that of *Chironomus* and *Dicranota* (16, 17). Three caeca is an unusual number, many caeca being found in *Chironomus*, eight in *Anopheles* and a few other larvae, four in a number of species, and two in others.

The posterior caecum is also unusual although Dufour found a "caecum latéral" in *Tipula lunata*, which, however, opened from the intestine and not from the mesenteron as is the case in the *Bibio Johannis* larva. Four is a common number of Malpighian tubes, but they usually enter the alimentary canal separately.

The oesophageal valve is fairly primitive, considerably more so than that of *Simulium* or *Chironomus* (16, 17) or *Anopheles* (12). It considerably resembles the valve figured by Holmgren (11) in *Mycetophila ancyliformans*, but is relatively shorter.

The structure of the cardia is also similar to that shown by Holmgren, in having first a regular epithelium of columnar cells, followed by a considerably folded region. In *Bibio Johannis* however there is a space between the two parts of the oesophagus forming the valve, which contains muscle fibres, and is more like that of *Dicranota*.

The peritrophic membrane is very common in Diptera, its length varying considerably. In this larva as in many others the membrane appears to arise from the anterior end of the cardia.

In the general features of its morphology the larva of *Bibio Johannis* bears a closer resemblance to the larvae of the Mycetophilidae than to any other group. This resemblance appears to be due to the fact that the two families are phylogenetically closely related. The possibility, however, that certain of the characters may be the result of convergence due to similarity of habitat must not be overlooked.

6. THE PUPA.

The larvae pupated on March 25th, the pupa being formed in an oval cell of soil, the last larval skin being in the cell with the pupa. The cell was considerably larger than the pupa, and quite smooth, and looked as if it had been formed by the larva pressing outwards in all directions.

The pupa is 7 to 8 mm. long, about 2 mm. broad across the thorax and 1·3 to 1·5 mm. broad across the abdomen.

The cuticle is smooth and white at first, but soon appears darker as the parts of the imago darken and show through owing to the transparency of the cuticle. The abdomen throughout is light in colour, as the abdomen of the imago does not darken completely until after it has emerged.

The pupa of the female is distinctly larger than that of the male particularly in the width of the abdomen.

The head is flat below and is pressed down on to the prothorax. The antenna cases are short and extend little more than half way across the eyes. On the anterior end of the head is a stout process directed forwards, which covers the ocelli of the imago. The cases of the mouth-parts are distinct. The thorax is short and thick, and the mesothorax is considerably the largest segment.

The leg-cases lie side by side, touching those of the other side in the median dorsal line, and extend to about the middle of the first abdominal segment. The cases of the first pair of legs are wholly visible, those of the second pair almost so, while only the extremities of the third pair are left in sight. The remainder is covered by the wing-cases, which do not quite meet and extend a little farther back than the leg-cases (Plate II, fig. 3).

Dorsally there is a slight ridge running from the posterior edge of the mesothorax to the process on the head, and along this ridge the cuticle splits for the imago to emerge (Plate II, fig. 2).

The prothoracic spiracles project slightly in a dorso-lateral position. The boundary between the prothorax and the mesothorax is not marked on the dorsal side, while ventrally the leg- and wing-cases cover almost the whole of the thorax. The abdomen is long, straight and slightly flattened dorso-ventrally and consists of nine segments, the first six of which are about equal. After the sixth segment the abdomen tapers slightly, the last segment having the form of a blunt cone. The last segment bears a pair of stout processes slightly dorsally near its tip, which are nearly as long as the segment.

Apart from these processes and the spiracles, the cuticle of the pupa is bare.

The abdomen bears a pair of spiracles on each segment except the eighth. These spiracles project from slightly before the middle of the sides of the segments.

7. NOTE ON THE IMAGO.

The adults emerged from the pupa on April 9th and the following days, but their emergence was probably hastened by the warmer conditions under which they were kept.

The number of individuals of the different sexes, including the pupae which were preserved as well as the adults which emerged, were, males 20, females 7, showing a considerable preponderance of males.

8. ECONOMIC SIGNIFICANCE OF THE BIBIONIDAE.

There appears to have been a considerable amount of uncertainty as to whether larvae of this family are destructive to the roots of cultivated plants. A number of instances are recorded of such damage by certain species of this family, although Scharov (22) considers them harmless.

Various species are recorded by Theobald (26) as attacking the roots of oats, grass, lettuces, seedling cabbages and young flower plants, while hops appear to be particularly badly attacked, especially by *Dilophus febrilis* and *D. vulgaris* (20, 27).

Carpenter (4) reports finding larvae of *Bibio Marci* feeding on potatoes. while Collinge (5) states that *Bibio Marci* damages tomatoes, young conifers, seedling ash and young spruce. He further adds that *Bibio Johannis* damages larch seedlings and hop roots, and he considers that these larvae are introduced in manure or leaf-mould. The larvae of *Bibio Marci* are also recorded by Gillanders (10) as injuring ash seedlings.

Other records mention *Bibio hortulanus* larvae as damaging sugar beet(25), spring barley and wheat(18), the damage in the latter instance being so severe that many fields had to be ploughed up and resown.

Curtis(6) states that *Dilophus febrilis* larvae cause much mischief in gardens. He found them on the decayed portions of planted potatoes and also on the tubers, and in flower pots.

Larvae of *Bibio abbreviatus* are reported by Strickland(24) to have damaged celery plants. The soft tissue between the fibro-vascular bundles of the stalks was eaten away to a depth of 1·5 mm., and the larvae also burrowed slightly into the stalks. Owing to the large number of larvae the damage was extensive. In this case the larvae are thought to have been brought to the plants in manure.

Some instances of believed damage by the adults of this family are recorded. Lyonet(14) believed that the adults of *Bibio Marci* damaged the buds of fruit trees, and other writers believed that the adults of this family damage fruit blossom, but it is unlikely that the damage was due to this cause, the flies being more probably beneficial in assisting pollination(31). The adults of *Dilophus febrilis* are mentioned as being believed to cause damage to hop-cones, but any damage is probably due to their being dried in the cones(27).

Bibio albipennis, which appears to be very common in the United States of America, is considered to be harmless. The larvae are said to feed on dead leaves and stems(7), and they are also mentioned as having been found feeding on oak galls(29), which appears unusual, unless the galls had fallen to the ground.

The larvae of Bibionidae appear to occur very commonly in cow-dung and manure(8, 15) and it seems probable that in many instances the larvae have been carried to the plants which they were found damaging in manure. Many of the plants mentioned as being attacked are usually grown with heavy applications of this material.

Theobald(27) states that vaporite and injections of bisulphide of carbon into the soil were found to kill the larvae. He also recommends trapping the larvae by burying old roots in the soil, and then digging them up early in March and destroying the larvae found feeding on them. He also found soot and lime effective in dealing with the larvae.

Carpenter(4) states that the larvae "seemed to be but little affected by the dressings usually applied for killing or repelling underground insects." He states that various birds, including domestic poultry, devour the larvae readily. *Bibio* larvae of several species have been found in the food of rooks, starlings and chaffinches(28).

Spraying infected land with a solution of Chili saltpetre in early spring, and harrowing in autumn or early spring after spreading quicklime on the field are recommended (25), while ploughing deeply and rolling at the time of pupation, has also been found satisfactory (18), contact poisons being said to have very little effect.

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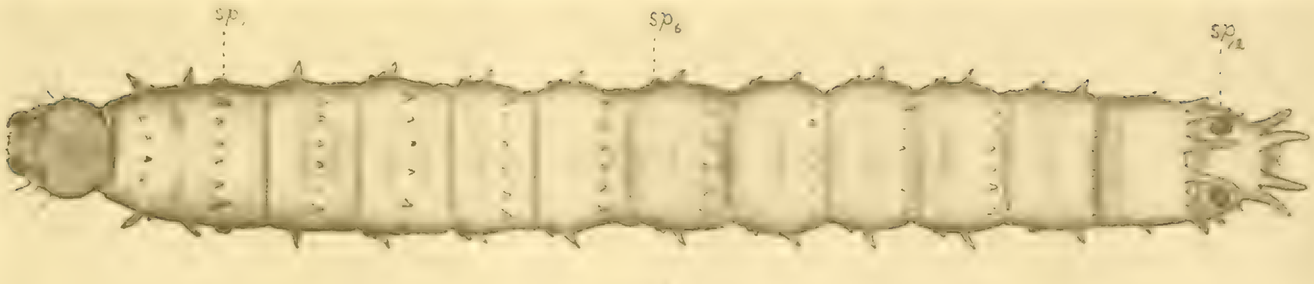
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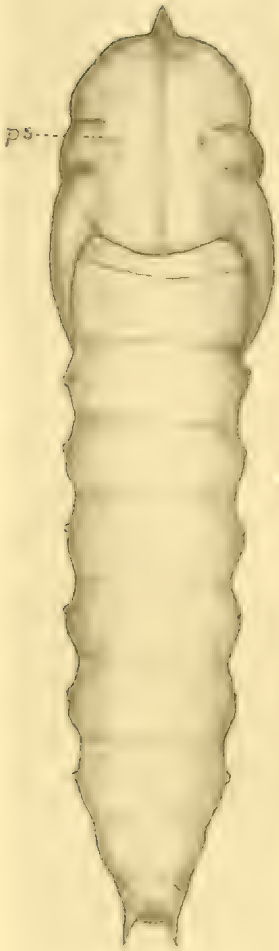

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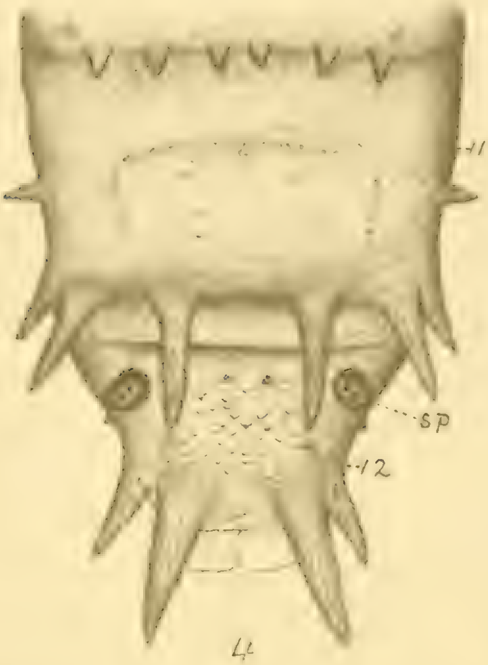

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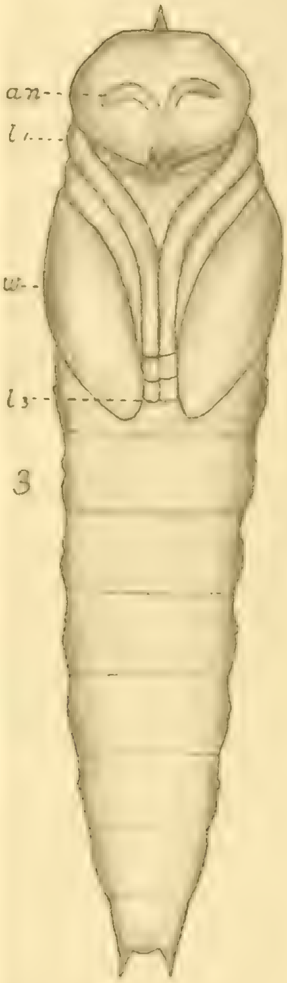

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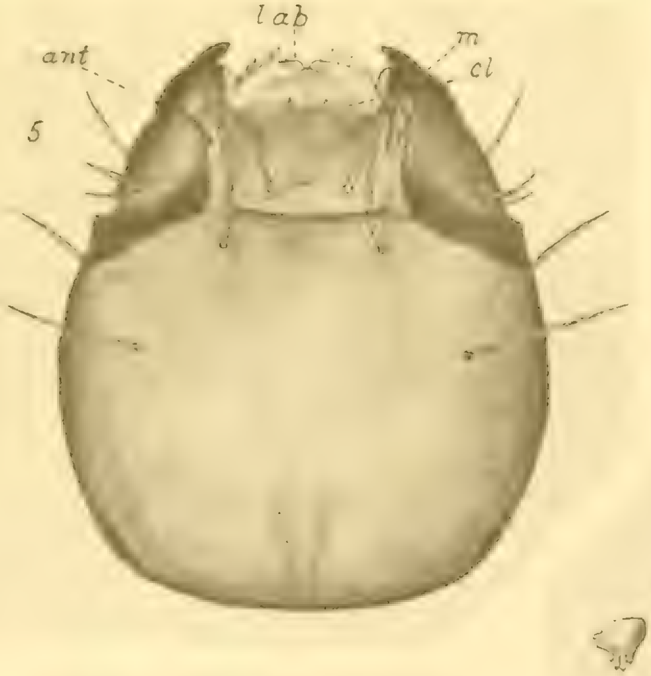

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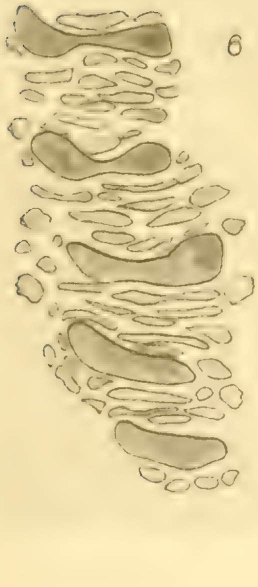

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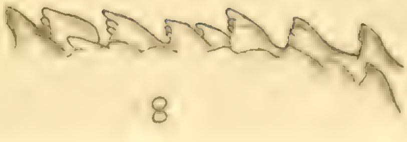

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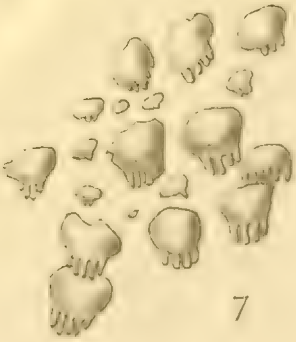

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10. DESCRIPTION OF PLATE II.

Fig. 1. Almost fully grown larva of *Bibio Johannis*, dorsal aspect. *sp.* spiracle of first segment; $sp._6$ spiracle of sixth segment; $sp._{12}$ spiracle of twelfth segment. × 12.

Fig. 2. Pupa of *Bibio Johannis*, dorsal aspect. *ps.* prothoracic spiracle. × 12.

Fig. 3. Pupa of *Bibio Johannis*, ventral aspect. *an.* antenna case (right); *l.* leg-case of right leg of first pair; $l._3$ leg-case of right leg of third pair; *w.* wing-case (right). × 12.

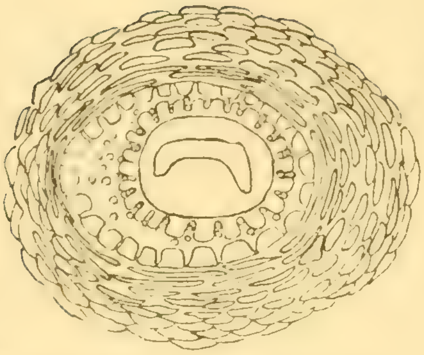
Fig. 4. Posterior end of larva, dorsal aspect. 11, eleventh segment; 12. twelfth segment; *sp.* spiracle of twelfth segment. × 30.

Fig. 5. Head of larva, from above. *ant.* left antenna; *lab.* labrum; *m.* right mandible; *cl.* clypeus. × 60.

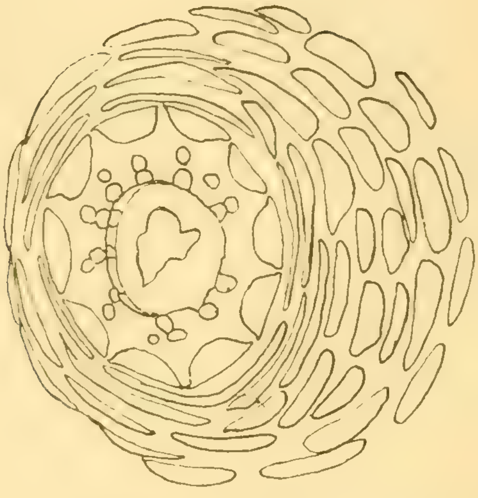
Fig. 6. Part of an intersegmental region, surface view. × 180.

Fig. 7. Portion of cuticle, surface view. × 180.

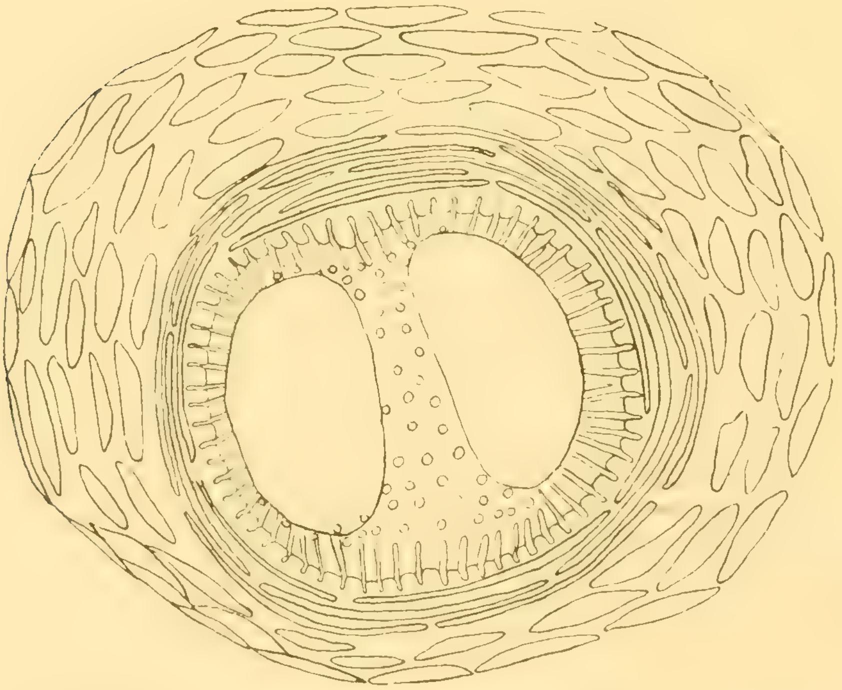
Fig. 8. Ditto, lateral view. × 180.



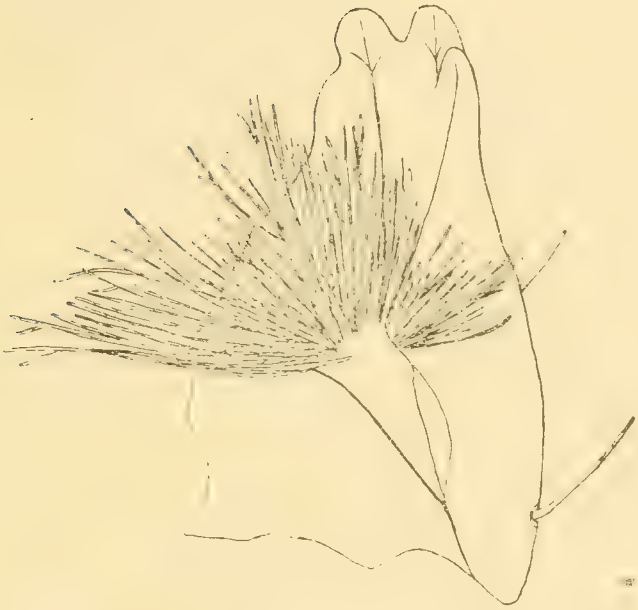
Text-figure 1. Left spiraclé of first segment of larva. × 360.



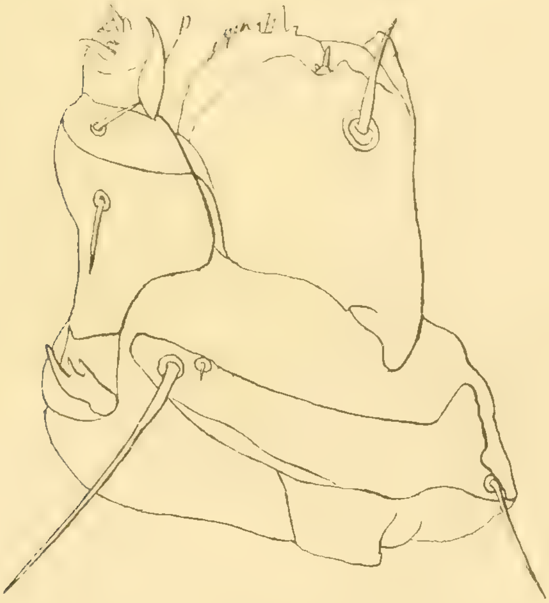
Text-figure 2. Left spiracle of sixth segment of larva. × 790.



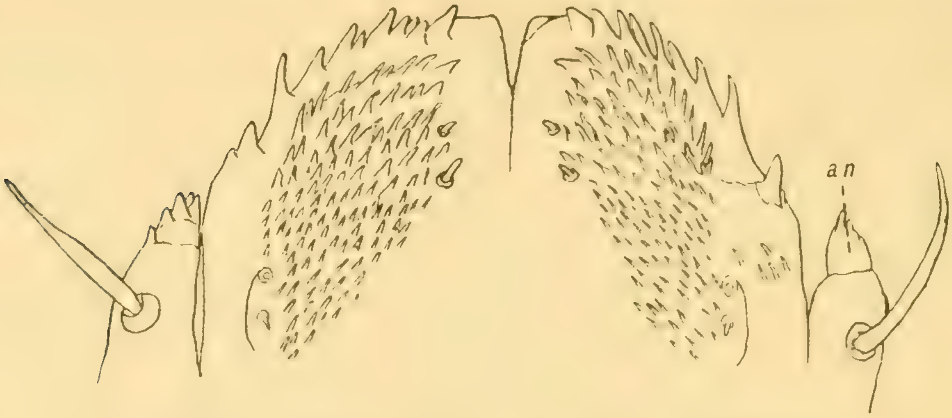
Text-figure 3. Right spiracle of last segment of larva. × 360.



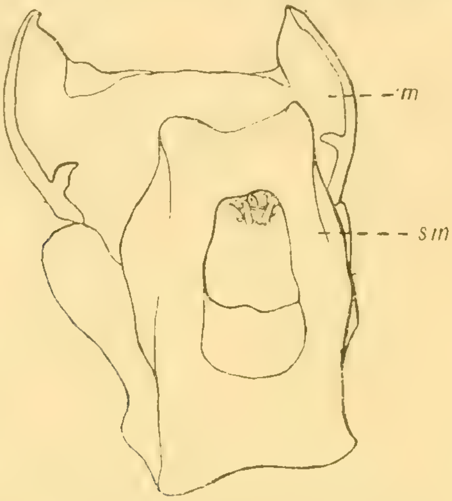
Text-figure 4. Right mandible of larva viewed from the left. × 180



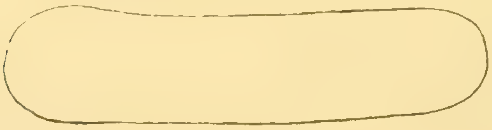
Text-figure 5. Right maxilla of larva from below. × 180.
p, maxillary palp.



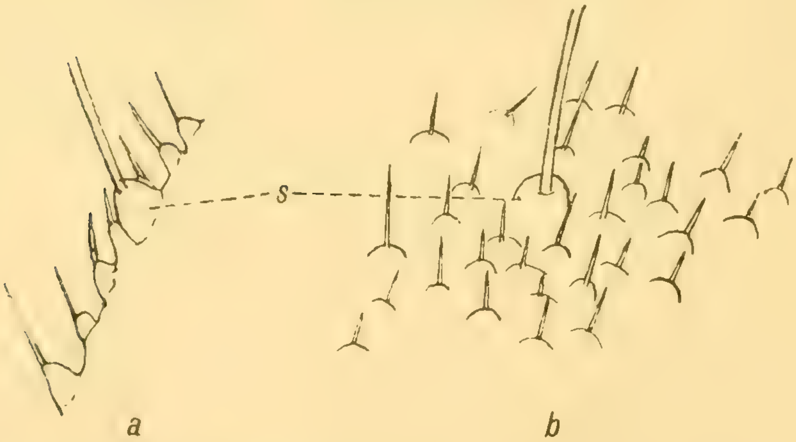
Text-figure 6. Labrum of larva from below. *an*, antenna. × 200.



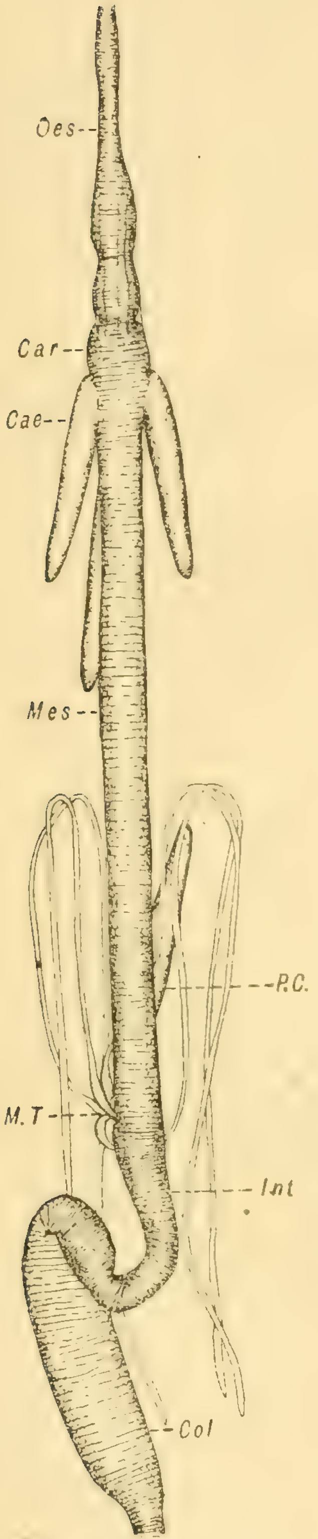
Text-figure 7. Labium of larva from below. × 200.
m, mentum. *sm.* sub-mentum.



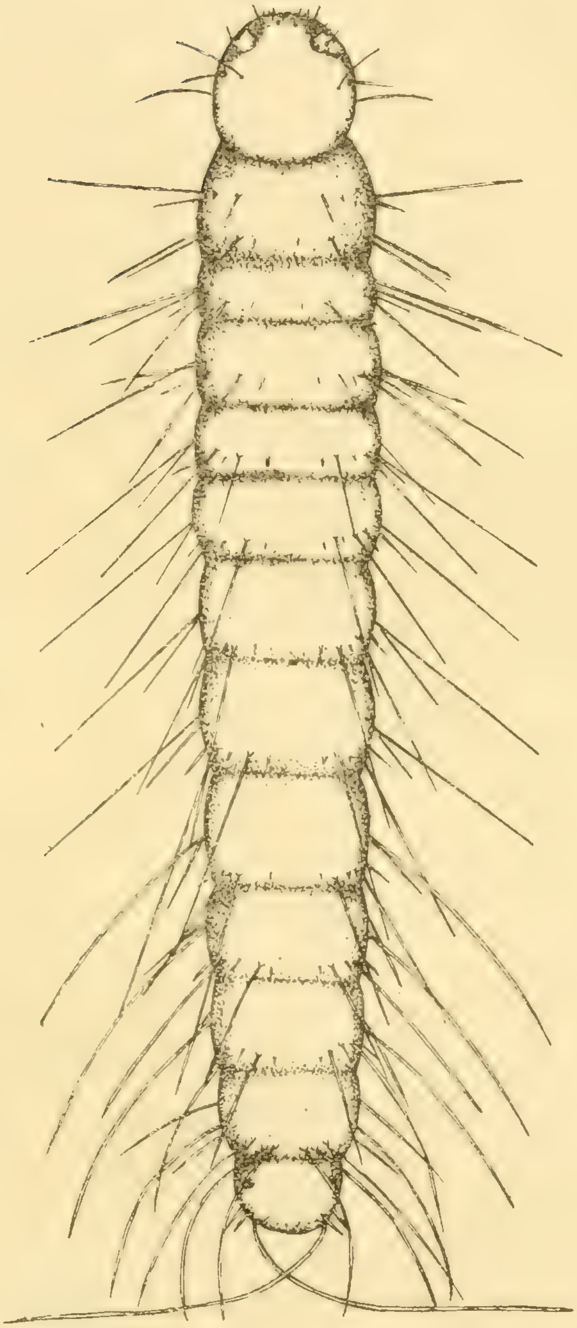
Text-figure 8. Egg of *Bibio Johannis.* × 80.



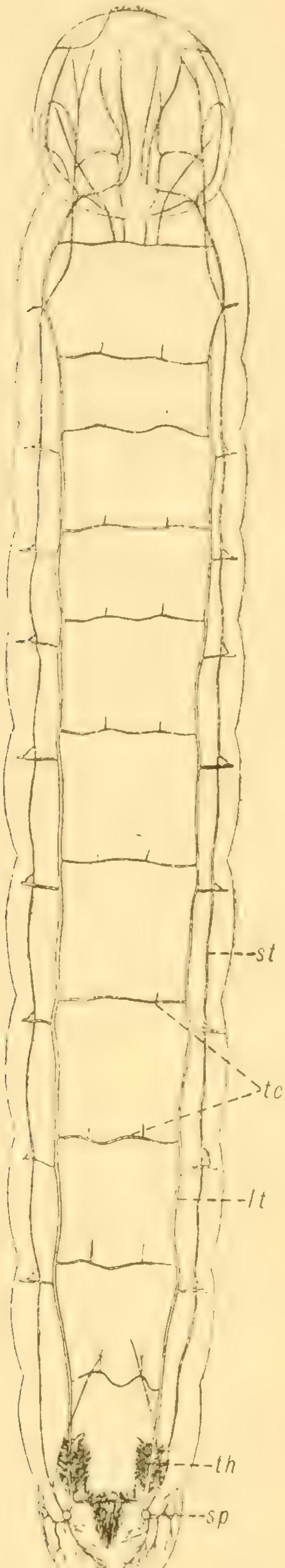
Text-figure 11. Processes on cuticle of newly hatched larva. × 600.
a, Lateral view; *b*, surface view. *s*, base of long seta.



Text-figure 9. Alimentary canal of *Bibio Johannis* larva. *Oes,* Oesophagus. *Car,* Cardia. *Cae,* Caeca. *Mes,* Mesenteron. *P.C.* Posterior caecum. *M.T.* Malpighian tubules. *Int,* intestine. *Col,* Colon.



Text-figure 10. Newly hatched larva of *Bibio Johannis*, dorsal aspect. ×90.



Text-figure 12. Tracheal System of newly hatched larva. × 120. *lt*, Main longitudinal trunk. *sp*, Spiracle. *st*, Secondary longitudinal trunk. *tc*, Transverse connectives. *th*, Tracheae to the heart.

TWO EXPERIMENTS IN HOUSE FUMIGATION

By H. MAXWELL-LEFROY.

Imperial College of Science and Technology.

House fumigation with hydrocyanic acid gas or carbon bisulphide is no new thing and some years ago Mr C. W. Mason and I fumigated the greater part of the new laboratories of the Pusa Agricultural College, a building over 400 feet long. But in the cases I have had experience of the difficulties were slight and in the present cases were considerably greater.

In the first case the house was situated in one of the suburbs and was infested with the house mite (*Glycyphagus domesticus*, etc.). The use of paraffin, formalin and sulphur dioxide in single rooms had driven the mites over the whole house and the lady of the house was in despair, having struggled without success for some years. It seemed likely that only very drastic treatment in every part of the house simultaneously would succeed and it was necessary that this should not simply mean the rooms but the floors, staircases, outhouses and even the coalshed.

It is known that hydrocyanic acid gas has a very small power of penetration in grain and it was fairly certain that it would not penetrate the floors if simply generated in the room: so carbon bisulphide was used for floors and at the same time hydrocyanic acid gas was generated.

The house was an ordinary three story detached one with twelve rooms, no cellars or basement. The houses on each side were less than twenty yards away. The volume of the house was approximately 31 feet cube or 30,000 c. feet. The individual rooms were not measured but we tried to fill the whole house evenly and the amounts were allotted roughly according to the size of the room; all doors were left open inside the house.

The quantities employed were 40 lbs. cyanide 98 per cent., 40 lbs. sulphuric, and 54 lbs. carbon bisulphide. Including larder, bathroom, etc., 21 lots of cyanide and 23 lots of bisulphide were used as follows:

Cyanide: 1 lot of 6 lbs. in the hall;
3 lots of 3 lbs. in the larger rooms;
11 lots of 2 lbs. in the smaller rooms;
6 lots of $\frac{1}{2}$ lb. in the larder, etc.

Bisulphide: 1 lot of 4 lbs.;
7 lots of 3 lbs.:
14 lots of 2 lbs.:
1 lot of 1 lb.

The bisulphide was apportioned according to the floors, landings and staircases. The procedure was as follows; a list was made of the rooms and the special places requiring doses either of cyanide or bisulphide: on this the quantities were estimated, the chemicals were obtained and the owners went out. With the help of Messrs Davidson and Awati the fumigation was done between 10.30 a.m. and 1 p.m.

The acid and water was mixed in the yard in proper quantity for each room in a jug or basin and put there; the cyanide was weighed into pieces of cloth about 20 inches square and placed beside each basin; rooms were allotted and signals fixed: the bisulphide was then measured into jugs and placed beside the cyanide.

All being ready and the sequence of operations fixed for each floor, we commenced at the top, each pouring his dose of bisulphide down the floor and standing by with the cyanide: at the signal the cyanide was dropped into the acid and each man bolted out: in this way the floors were done: the most difficult was the ground floor, where there were seven charges of cyanide and nine of bisulphide to be let off by three men but we emerged without mishap.

The house had been prepared by closing all openings, opening out cupboards, books, etc., and taking up all carpets; where possible a plank was taken up in the floor. All fires were out, all chimneys closed, all gas off.

Success turned on penetration of the floors, which I hoped to secure by pouring down bisulphide. The strengths were worked out at 1 lb. of cyanide to 700 cubic feet and 1 lb. of bisulphide to 500 cubic feet, assuming each to penetrate the whole house. The hydrocyanic probably never penetrated the floors and the bisulphide did not saturate above floor level, so each was much stronger, certainly at first.

The cost of chemicals was:

	£	*s.*	*d.*
40 lbs. cyanide 98 per cent. fused at 1*s.* 2*d.*	2	6	8
40 lbs. sulphuric acid coml. at 1½*d.*	0	5	0
54 lbs. bisulphide at 4*d.*	0	18	0
	3	9	8

The house was visited twenty-six hours after the fumigation and the fumes in the ground floor were then so strong that it was impossible to stay and I had difficulty in getting out. So the house remained shut for a total period of sixty-nine hours when it was then opened up.

The occupiers moved in a few days later and the lady of the house, who had waged war on the mites for years, searched and found live ones in the books and in one attic. A few days later they were found also on the banisters and on the piano. Apparently this was all and three months later the lady of the house wrote: "We shall not need any further fumigation for the present: indeed I am hopeful we are practically free of the mites. I have seen none on the furniture for some time though I fully expected to in the last week's warm weather." Two months later the house was reported clear entirely.

It seems likely that had the fumigation been repeated fourteen days later, even on a milder scale, every ultimate mite would then have been destroyed. It must be remembered that not only is there the egg as a resistant stage but also the curious hypopial stage, in which the mite encases itself and passes into a resting stage. In either of these forms fumigation would scarcely kill all in the most sheltered positions. The experiment showed (as far as one alone can), that:

1. Cyanide and bisulphide can be used together.
2. The escaping vapours are not offensive to neighbouring houses.
3. Gas escape from an ordinary house is slow.
4. Bisulphide vapour escapes slowly from ordinary ventilated floors (these not being closed).
5. The cost of fumigation is not excessive.
6. Neither gas damages the contents of a house.
7. A single application at these strengths may be sufficient, by destroying practically all the mites and making further increase impossible.

From observation of the results it appeared as if the bisulphide was not very effective even at this strength: one larder was treated very heavily with bisulphide as it contained food that might absorb the hydrocyanic acid: yet here mites were found.

The second case may be more shortly told. It was a two story house of 18,000 cubic feet capacity, heavily infested with book-lice (*Psocidae*), which were of the usual wingless type found in houses. The infestation had lasted from April to August and was proving detrimental to the health of the lady of the house. From an examination made under the floor, it appeared as if the two foot space below the floor was not well ventilated, was damp, the beams covered with fungus and the whole formed the main breeding-place of the Psocids, which came up through the boards and spread over the house. As in the other cases, partial treatment had driven them from room to room.

Fumigation was done as before but using tetrachlorethane instead of carbon bisulphide. 12 lbs. of 130 per cent. sodium cyanide was used, and 12 lbs. of tetrachlorethane. The cyanide was not weighed but divided by eye, as it was in lumps, and 10 lots were used in the house, two small lots in the outside coal cellar and privy. This house was only semi-detached and I feared gas escape to the next house: but the builder assured me this was impossible as there was no communication of any sort.

The fumigation was done with the aid of Mr Scott and Mr Lloyd: forty-eight hours later I visited the house, was able to go straight in and could detect no smell except that of tetrachlorethane when I removed the paper from the outside ventilators leading from the space under the ground floor. There was no complaint from neighbours, no damage to property. The occupiers who were away, returned and have now reported as follows: the house is completely cleared but reinfection has been found to be occurring at a dormer window where insects have been found coming in. This spot has been treated with a miscible wood creosote and varnish and reinfection has ceased. There has been no reinfection from the floors at all and no live insects seen in the house. The cost of treatment was:

	£	*s.*	*d.*
12 lbs. cyanide at 1*s.* 6*d.*	0	18	0
24 lbs. acid at 3*d.*	0	6	0
12 lbs. tetrachlorethane at 1*s.* 6*d.*	0	18	0
	2	2	0

In this case, no particular preparation was made except to open up cupboards, etc.: no damage of any kind was done to anything in the house and the owners are completely satisfied.

In both cases I attribute great weight to the opinion of the lady of the house, utterly distracted and weary of the plague: and in both cases residence in the house after treatment has not been followed by a resumption of the attack.

It is difficult to get cases of this sort but I am satisfied that fumigation with hydrocyanic acid with carbon bisulphide or tetrachlorethane is a feasible and effective method even in a town, provided reasonable precautions are taken. I imagine this fumigation would be effective against every form of insect life except possibly the bed-bug but a house so infected has not been available.

THE LOCUST IN CYPRUS

By W. P. DELANE STEBBING, F.G.S.

The Locust plague in Cyprus which so many early writers have mentioned and which was one of the problems which had to be grappled with on the British occupation in 1878, is now almost a thing of the past. But while locusts are usually thought of as large insects, such as the Syrian species with its orange body and brown-blotched wings, the one which has to be dealt with in the island, and was an annual plague, is a small indigenous brown-marked species of undistinguished appearance known as *Stavronotus cruciatus*. This small locust, which dwells on rocky and poor land from which, in its larval walking and hopping stage, it invades the cultivated areas near by, in its normal state is not migratory nor is the perfect insect able to take long flights. The damage it did was due to its general distribution and to ignorance of the creature's habits. With Eastern fatalism it was a plague of God and that was enough, while there was the inability, intensified by a natural aversion to combine forces, of a poor and sparse population to cope with it.

Like the poor, this locust is always with the islanders and only preventive measures continued from year to year could be satisfactory. The main methods by which the plague has been made negligible are three:

1. Egg collecting—easily done as the egg masses are always laid in light soil bordering the fields.

2. Stopping the crawling larval hosts in their progress by trenches on the further side of which were screens topped with a strip of American cloth. As they were unable to surmount this they fell back into the trench where they were suffocated by those coming after; and

3. Sprinkling feeding areas with a bacterial "cultivation" which gave them an epidemic disease.

It has not been necessary to use the second of these for many years and the annual expenditure on the first is almost negligible; but as a watchful eye has still to be kept on the trouble there are annual grants for the employment of the third, and a large amount of the "cultivation" is kept in the Government laboratories. But, along with other war economies in Cyprus, agriculture has had to suffer, and although it is said that the locust danger is a thing of the past it is a subject of controversy as to whether the plague has been combatted or if economy has had a say in this matter.

In comparison with the Cyprus locust the Syrian migratory species is a far more formidable creature and its ravages, when it appears, are so much more serious that many of the older accounts must have referred to these invasions from over seas. Several of them speak of flocks of a small bird which suddenly appeared in the island with the insects and ate up so many that the plague was minimised. Van Bruyn recounts how "in the year 1668 throughout the island, but especially in the country round Famagusta, there was such a vast quantity of locusts that when they were on the wing they were like a dark cloud through which the sun's rays could scarcely pierce."

Early in 1915 news reached Cyprus that swarms of locusts were ravaging parts of Syria. Then, that numbers had been found along parts of the coast both north and south of Famagusta in the E. of the island, and that one of our cruisers which put in at that port had passed through a cloud of them on her way and had many settle. The first swarms to arrive were few in number and were not ready for egg laying. A little damage was done in gardens and, as is the Cypriote nature, a great-to-do was made about it; but with the aid of Government grants under the supervision of the Treasury—not the Agricultural Department as one might expect—most of the locusts were caught in the early morning by knocking them off the trees where they clung heavy with the night dews. This measure for the adult insect is the most effective. After egg laying had taken place digging over the soil and collecting the masses was usefully practised, and—after hatching—for both native and foreign species, spraying with a paraffin mixture, the invention of the Entomologist to the Agricultural Department. The egg masses collected came to such an amount that one of the old Turkish storehouses in Famagusta, formerly a church of Venetian date, was filled with them. The sticky eggs are laid by the female in a hole which she bores in the loose soil and form an agglutinated mass covered with grains of earth.

In the latter part of the summer fresh swarms of locusts made their appearance while others were ravaging Egypt. This time some appeared on the northern coast while large numbers invaded spots in the southern part of the island. Some of these latter did a great deal of damage among the vines and olives but they were not much inclined to settle and start egg laying. Each village did as much as it could to keep them on the move, the inhabitants going out into the fields with sticks and old tins or anything with which they could make a noise. On the uncultivated hill tops piles of brushwood were collected and at the alarm of a swarm of locusts appearing these were fired so that the drifting smoke should terrify the insects. At night the scattered fires now rising now falling in intensity had a rather alarming look from the heights of Troödos before their necessity was realised. The threatened ravaging of the Omodhos district, which is one of the richest wine producing districts of the island, aroused everyone to exert themselves so that little damage was done at this period. A swarm of locusts appeared over the village of Omodhos on the afternoon of its great fair and was heralded by the ringing of its church bells, while departing strangers with their strings of mules and donkeys were hurried on their way by the beating of tin cans. Most of the swarms of this plague, which can have formed only a minute proportion of the hosts that left the shores of Syria, were loosely composed and as they did not darken the sun their fluttering flight was pretty to watch. This flight is very deceptive and made the writer think that he could catch scores of the first swarm he was among. But it was very rare for one to alight and without a butterfly-net it proved impossible to make a capture, although a boy joined in the hunt. On another occasion at midday a swarm was resting among scrub with much bare ground but seemed equally wide awake. Although the insects did not keep in the air no quickness availed to track one to earth as their flight was too long to keep marking the spot at which some particular one dropped.

After the birds among natural destructive agencies there is no doubt that the various species of lizards do an immense amount of good in keeping down insect life. Their numbers prove this. If a mere man could not catch a locust the large ugly brown rock and tree climbing lizard known as *Agama stellio* could; and an attempt to rob one of his prey on the slopes of Troödos above the vineyards was frustrated by his disappearance into a hole. At this level Troödos although tree covered, evidently had no attractions for locusts as the writer only saw a couple of other specimens at any height. It was a complete bar between the cultivated valleys to N. and S.

The vine growing district south of Troödos, which consists of a much denuded belt of decayed volcanic rocks succeeded by a wide limestone plateau cut up by deep river gorges, is noteworthy in the possession of a factory where wine is made on modern methods and spirits are distilled. The Perapedhi port is well known in the island among the British residents but the firm being largely German, although under British management, and the output going to Hamburg meant the closing down of operations before the vintage of 1915. Up to a late date the manager hoped to run as usual and to profit by the entry of Greece into the war on the Allies' side. This would have meant the flooding of the Alexandria market with cheap Greek wines, the lowering of the prices of the native Cyprus wines and the consequent ability of the Perapedhi Wine Company to buy large quantities at cheap rates from which the firm would have been able to distil spirit at a good profit. But this was not to be and the manager, like many others in their outposts of civilisation, left the island to take up war work in the old country. His garden, which sheltered a swarm of locusts one morning for a few hours, was a wonderful example of productiveness under intelligent management, and of what could be grown in the way of fruit trees which would resist severe winters.

The following quotation from the travel observations of Dr Thomas Shaw on the Syrian locust may close these notes. His life on the southern shores of the Mediterranean gave him good opportunities of observing them. "Those," he says, "which I saw in 1724 and 1725, were much bigger than our common grasshoppers, and had brown spotted wings, with legs and bodies of a bright yellow. Their first appearance was towards the latter end of March, the wind having been for some time from the south. In the middle of April their numbers were so vastly increased, that in the heat of the day they formed themselves into large and numerous swarms, flew in the air like a succession of clouds; and, as the prophet Joel expresses it, they darkened the sun. When the wind blew briskly, so that these swarms were crowded by others, or thrown one upon another, we had a lively idea of that comparison of the Psalmist, of being tossed up and down as the locust."

MUSSEL BEDS; THEIR PRODUCTIVITY AND MAINTENANCE

(THE MUSSEL BEDS OF CARDIGAN BAY)

By FRANK S. WRIGHT.

Zoology Department, University College of Wales, Aberystwyth.

The present paper deals with some of the results of my observations on the mussel beds of Cardigan Bay, from September 1915 to August 1917. These investigations were carried out on behalf of the University College of Wales, Aberystwyth, and included an experimental transplantation of mussels on a fairly extensive scale, in the estuaries at Aberdovey, Barmouth, and Portmadoc. The Cardigan Bay mussel beds had become greatly depleted through over fishing, which, in conjunction with pollution troubles, had brought the fishery to a very low ebb. The work has included outdoor observations, as well as more detailed work in the laboratory. Although the Sea Mussel (*Mytilus edulis,* L.) has received a great deal of attention in the past, and, therefore, some of the facts, *per se,* contained herein may not be new, yet it is believed that their presentation in an especial manner may be useful. The laboratory work has been of a somewhat detailed character, and, although a great deal of time has been devoted to it, much of it remains unfinished. I refer more particularly to that portion which deals with the food material of *Mytilus,* which, while it bears more or less directly upon the subject-matter of the present paper, cannot be more than touched upon here. It is hoped to embody these results in a separate paper at a later date.

The beneficial results to the Cardigan Bay mussel fishery which have resulted from the restocking of the beds (in the spring of 1916, and, less extensively, 1917), as well as the possibility of carrying out the investigations, are due to grants from the Board of Agriculture and Fisheries.

The work was confined mainly to the Dovey Estuary. It is within easy distance of Aberystwyth, the mussel beds there are easily accessible, and a room was used as a laboratory within a few yards of the shore.

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CARDIGAN BAY AND ITS ESTUARIES.

The following account of Cardigan Bay and its more important inlets is, in the main, abridged and otherwise modified from Mr C. L. Walton's description in the first *Report on Investigations towards the Improvement of Fisheries in Cardigan Bay and its Rivers,* published in 1913 by the University College of Wales, Aberystwyth.

Cardigan Bay occupies a considerable portion of the west coast of Wales. It is bounded on the north by the southern shores of Carnarvonshire, and its central portion comprises the entire coastlines of Merionethshire and Cardiganshire, while its southern limit is the North Pembrokeshire coast. It may be said to lie eastward of a line drawn from Braich-y-Pwll in Carnarvon to Strumble Head in Pembroke, which two places are distant some fifty-five miles from each other. The total length of the coastline between these two points is about 140 miles. The whole area is relatively shallow, the thirty fathom limit lying just westward of the line mentioned above. Several causeways or spits (Welsh, *Sarn,* a paved roadway) project out to sea in the northern half of the Bay, often for several miles. Their landward ends are uncovered at low water. Such are Sarn Badrig, Sarn y Bwch, and Sarn Cynfelyn. High and steep cliffs bound the shores of the Bay, except where they are interrupted by the numerous river valleys, and the larger estuaries. We shall omit any mention of the former, as they do not concern us in this place, and confine ourselves to the Estuaries in which the mussel beds are found, namely the Estuary of the Glaslyn and Dwyryd rivers at Portmadoc, the Mawddach Estuary at Barmouth, and the Dovey (or Dyfi) Estuary at Aberdovey. It is in these places that the sea mussel finds the conditions suited to its habits. Patches of mussels occur at various places on the coast, where freshwater influence is felt, but, as the shellfish always remain stunted in growth, they are of no economic value. They might be employed to replenish depleted beds, if necessary.

The tidal sweep, assisted by the south-westerly winds on the west coast, is very strong. Where it meets the rivers, large storm beaches have accumulated, and, fronting the estuaries, sand bars (and sometimes dunes, as at the seaward end of the Dovey Estuary). This tidal sweep causes great alteration of the beaches from time to time, the stone and shingle being transported in a northerly direction along the coastline. C. L. Walton has shown how this factor has had an adverse effect on the fauna in certain parts of Cardigan Bay[1].

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[1] "The Shore Fauna of Cardigan Bay," *Journal of the Marine Biological Association of the United Kingdom,* Vol. x, No. 1, November, 1913.

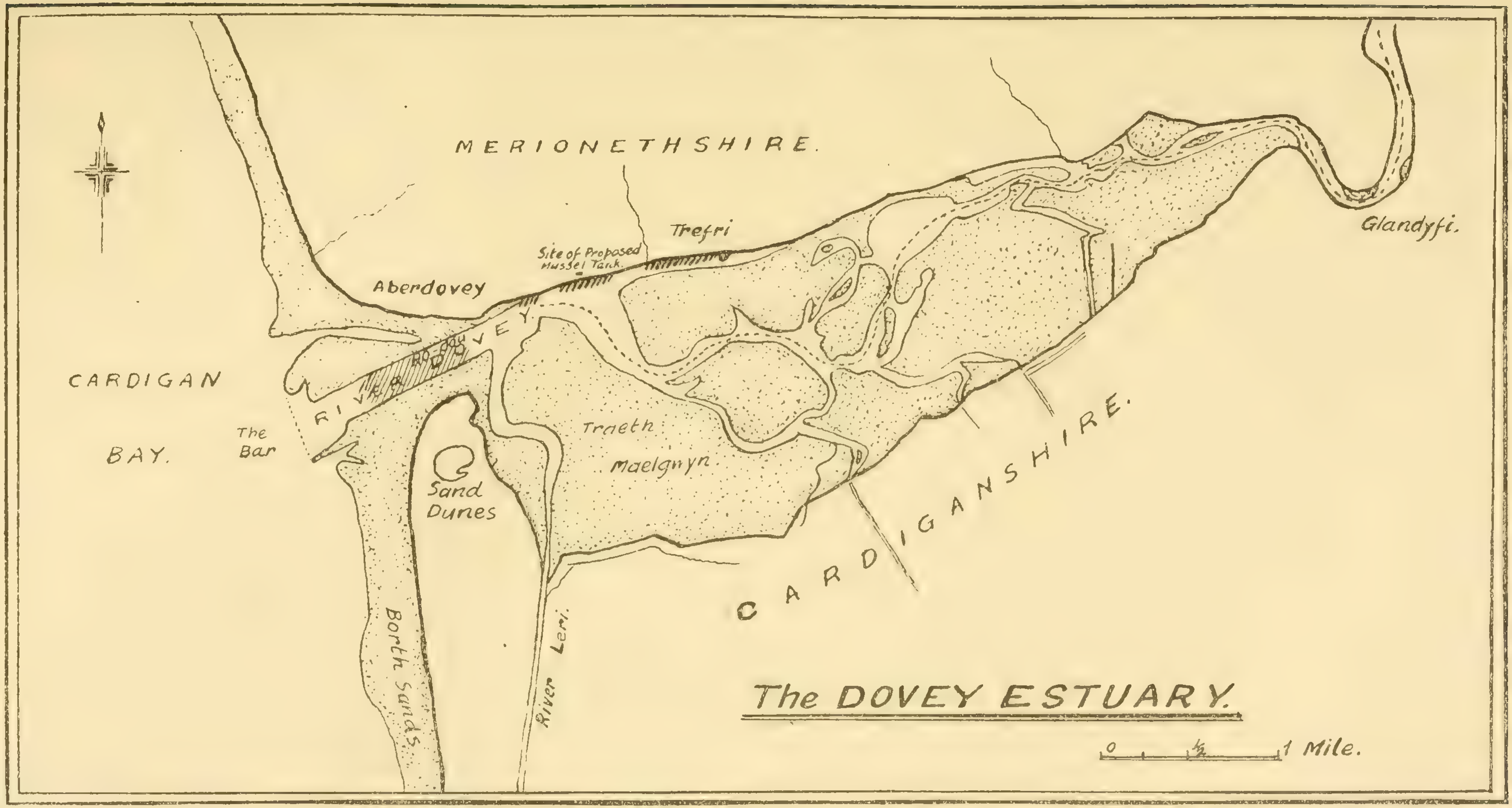
MERIONETHSHIRE.
Trefri
Site of Proposed Mussel Tank.
Aberdovey
Glandyfi.
CARDIGAN BAY.
The Bar
RIVER DOVEY
Sand Dunes
Traeth Maelgnyn.
Borth Sands.
River Leri.
CARDIGANSHIRE.
The DOVEY ESTUARY.
0 ½ 1 Mile.

Fig. 1. The Sketch-Map represents the Estuary at low water of ordinary tides. The Mussel Beds are represented—in an exaggerated manner—by means of slanting lines; thick, for the fishing-beds; thin, for the "seed"-bed, or scar. The present course of the River Dovey is, roughly, as indicated on the Map.

The Dovey Estuary (see Map).

It is necessary to give here a brief description of the Dovey Estuary, and of its mussel beds.

The estuary is a large inlet (some five miles in length), which divides the counties of Merionethshire and Cardiganshire. Its area is approximately five and a half square miles. The north shore is rocky and steep, but, on the south, it is bounded by that low-lying tract which we may term the Dovey Flats. A large sand bar lies across the entry of the estuary, and restricts it to a relatively narrow channel or neck. Such an estuary is termed a "bottle-neck." Within, its condition may best be described as sand-logged, and, consequently, with the exception of the actual channel (or channels) of the river, it is very shallow. Through the great stretches of sand, the river pursues a meandering course to its outlet. Its channel is subject to considerable alteration from time to time, through the agency of the banks of shifting sand. The stable sandbanks are populated by an abundance of cockles and their associates.

Although relatively shallow, it is yet obvious that a very large volume of water is contained in the estuary at high tide. This, having to ebb and flow through one comparatively narrow outlet, is apparently never wholly changed; for instance, within the estuary, the tide will have risen appreciably before it is able to check the outgoing current. Therefore matters constituting a possible source of contamination to the mussels may remain in the channel for a long time.

The river impinges at several points on the north shore, including nearly the whole of that portion fronting the town of Aberdovey and its neighbourhood, and westwards to the Wharf. The current formerly ran along the shore from Trefri to Penhelig Point (east of Aberdovey), but, at the present time, only a shallow gutter marks this old channel. For the most part, these places have been cleared of sand, and they are either rocky, or else covered with stony beaches. This portion of the foreshore shelves moderately gently to low-water mark of spring tides, and then very abruptly to the bed of the river. It is upon such rocky and stony areas (from about low-water mark of ordinary tides downwards), here of limited extent, that the mussel beds are situated. The sea mussel needs hard ground on which to anchor itself; but, where the current is not very swift, and there is a muddy bottom (as at Portmadoc), they are able to maintain themselves by becoming embedded in the mud, or by clinging to each other in clusters.

The history of the Aberdovey mussel beds (and, indeed, of the Cardigan Bay beds in general), is difficult or impossible to trace. It is safe to say that they have suffered many vicissitudes, as, with the slightest deflection of the river channel, portions of the beds are always liable to be covered by the sand, and their population killed. Such accidents have happened time and again; yet the current that destroys one bed may uncover another stony area, that, within a short time, affords a holdfast for a very populous colony of mussels.

The fishing grounds at Aberdovey, then, may be said to comprise a strip of the foreshore on the north shore of the estuary from Trefri Point to the Shipping Wharf, as well as portions of the river bed, etc. Their continuity is broken by occasional patches of sand, but, roughly, the length of the beds may be stated at one mile. Relative to the width of the inlet, this strip is a narrow one, and, in places, exceedingly so.

In all these situations, the mussel thrives satisfactorily, finding an abundance of food material, the necessary degree of freshwater influence, and other conditions suited to its habits.

In the three estuaries there are certain beds (often of large extent and occasionally supporting a crowded mussel population), where the shellfish grow moderately well, while yet never attaining a marketable condition. Such mussel beds will be described hereafter as "scars" (skears), for want of a more convenient term. They generally differ in several respects from the Lancashire mussel beds, properly so designated, however. The population of the Cardigan Bay scars remains poorly fleshed, and their shells, while usually free of *Balanus*, are for the most part very thin and fragile. The last statement applies only to such beds as become dry at long intervals. Otherwise the mussels are often stunted or deformed, thick-shelled, and thickly encrusted with *Balanus*. The repeated wetting and drying to which they are subjected cause the shells to become rough and unsightly. When the chitinous outer shell-layer (the periostracum) is lost, the prismatic layer becomes visible, which, because of its colour, has caused such mussels to be called "blue nebs" among fishermen. A large scar (probably several acres in extent, although, for various reasons, its exact area is difficult to ascertain), or bed of seed mussels occurs at Aberdovey, towards the Bar. It occupies a portion of the north bank of the river, as well as of its bed, and stretches from a short distance below the Wharf to within about half a mile of the Bar. A portion of this bed, on the north shore, becomes uncovered at exceptionally low spring tides, and this place is known locally as *Ro-ddu*.

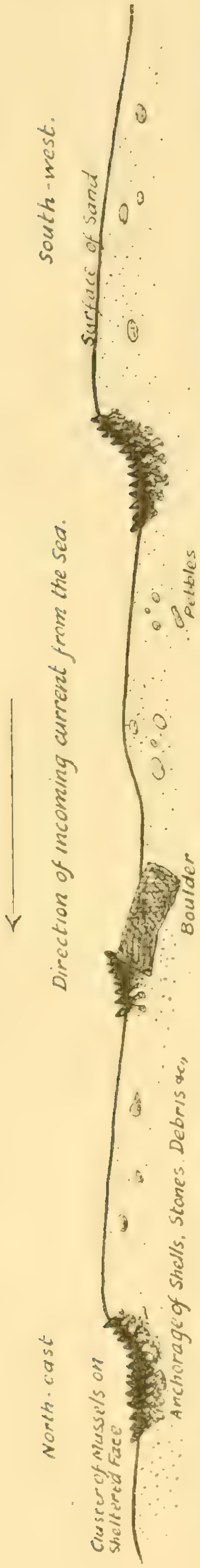
South-west.
Surface of Sand
Direction of incoming current from the Sea.
Pebbles
Boulder
Anchorage of Shells, Stones, Debris &c,
North-east
Clusters of Mussels on Sheltered Face

Fig. 2. Diagrammatic Section across a portion of the *Ro-ddu* "Scar" (Seed Bed). No scale. Mussels maintain themselves in the shelter afforded by the lee face of the Sand-Ripples, Boulders, etc., and are affixed to shells, stones and other objects which have collected there.

It will be interesting to note briefly the manner in which portions, at least, of this scar were formed, and how the mussels maintain themselves there (Fig. 2). The substratum is of moderately firm, clean sand, the surface of which is somewhat broken up into sand ripples. The steep (lee) faces of these front in an east-north-easterly direction. Against these ridges, cockle shells (which have been transported downstream by the river current from the extensive beds within the estuary), have accumulated, together with stones, water-logged wood, etc. On these materials, spat liberated by the mussels higher up the river has settled, and continues to settle year by year. As the shellfish develop, their byssus fibres fasten the whole together with a certain degree of firmness. As individual mussels die, they become covered by sand, and their shells afford a still better anchorage to their successors. Thus the bed is composed of a number of small colonies of mussels, clinging to the steeper sides of the sand wave ripples, and sheltered from the direct influence of the tidal current from the sea. Whether the whole of this somewhat "ragged" bed presents the same aspect is doubtful, but there is reason to believe that its deeper portions, which are always submerged, are rather more densely populated.

Lying, as it does, in the narrow neck of the estuary, where the tidal currents race most strongly[1], portions of the scar are probably always covered more or less with sand. This sand may be simply washed over it in quantity, from the river bed, or from banks of shifting sand, or else deposited from that held in suspension by the current, which is considerable (see paragraph on this subject in another place).

Although the sea mussel is an animal of rapid growth, yet, considering the relatively small extent of the fishing grounds dealt with in the present paper, it will be understood that these will soon become depleted unless restocked from time to time. It is not legal to take mussels of a size less than $2\frac{1}{4}$ inches, except in certain places (see the Bye-Laws of the Lancashire and Western Sea Fisheries District), and, from the time of the discharge of the ovum, probably three years will elapse before this size is attained, even under favourable conditions. The ova discharged by a single female of *Mytilus* during the spring and summer months are estimated to number from 10,000,000 to 15,000,000[1], the vast majority of which are destined to perish in various ways. So much so indeed, that, in order that the beds may be fished from year to year, it is necessary to restock them at the close of *each* fishing season—a matter of comparative ease.

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[1] Captain Enoch Lewis, of Aberdovey, informs me that, during spring tides, the current in the seaward portion of the estuary reaches a speed of about three miles an hour.

Myticulture is practised in several different ways[2], but the only one that need be mentioned here is the system of bedding, as practised in Britain. In a limited degree, transplantation has often been carried out by the fishermen concerned, and others, and accounts descriptive of the operations have appeared from time to time. Briefly, the shellfish are removed in quantity, from certain beds (seed beds), where they do not fatten, and redeposited in other situations where growth and fattening proceed with rapidity. Beds of seed mussels are usually present in the vicinity of the fishing grounds, and form nurseries or reservoirs from which they may be restocked when necessary.

The present paper is an attempt to discover the maximum productivity of mussel beds,—we might say the ideal productivity, and, like most other ideals, the present one might perhaps be regarded as unattainable. Yet, even if this should prove to be the case in practice, it is necessary to formulate a working hypothesis, and I venture to believe that an output such as is described later is well within the range of possibility. In its attainment, the chief factor to be taken into consideration is that the population may secure a sufficiency of food material[3], although there are other complicating factors to be considered. The degree of restocking necessary to maintain a maximum yield from the fishing grounds is also dealt with, etc. The data from which most of the subject matter of the present paper has been written, was collected during many visits to the Aberdovey (and other) mussel beds. The economic aspect has always been kept in view, but many of the facts contained in the following pages are probably new, or not yet published, and therefore they may possess some degree of scientific value in other respects also.

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[1] These figures apply to the American sea mussel, which is, however, of the same species. See article by I. A. Field in *The American Museum Journal*, October, 1916.

[2] See article by Professor W. A. Herdman in the *Report* for 1893 of the Lancs. Sea Fisheries Laboratory.

[3] See article by I. A. Field in *The American Museum Journal*, October, 1916.

In concluding these remarks, I shall quote an article by Professor Irving A. Field, whose works are so often mentioned in the following pages: "In the light of our present knowledge it is proper to say, when viewing a shoal of mussels, 'there is one of the greatest organisations in nature for making flesh food by a short and rapid process.' Surely the humble mussel is fulfilling a benevolent mission in the world[1]."

Acreage of the Aberdovey Mussel Beds.

It is not necessary to describe in detail the various beds, where, at Aberdovey, the marketable mussels are fished. It has been said already that they lie on the north shore, towards the seaward end of the estuary, where the slope is often very abrupt. This may be anything up to 50°, such being the slope of the river bank (here of solid rock) at Penhelig Point, just east of Aberdovey. In attempting to estimate the dimensions of the beds, therefore, it is not sufficient to discover merely their length and breadth, but the angle at which the river bank slopes has also to be taken into consideration. These several factors were borne in mind during my endeavours to discover the present superficial area of the fishing grounds, early in the present year (1917). Despite all care to ensure a reasonable degree of accuracy, the figures given below must be understood as being merely approximate. In fact, they are probably considerably below, rather than above, the actual figures.

The approximate total area of the Aberdovey mussel beds is 76,000 square feet (= nearly $1\frac{3}{4}$ acres).

(This does not include the great scar towards the Bar.)

The above figures were obtained from a personal knowledge of the ground, and information supplied by the more experienced fishermen, the whole matter being carefully checked on a large scale map, and in other ways.

Population of the Scars or Seed Areas.

In an endeavour to estimate the maximum potential productivity of mussel beds, when their area is known, it is necessary to find the greatest number of individuals of a given size able to live and thrive per square unit of measurement in natural conditions. Obviously, all the individuals in such a unit will not be of the same dimensions, but, in practice (and when checked by other methods) the results have proved fairly accurate.

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[1] I. A. Field in *The American Museum Journal*, October, 1916.

I found that the only place which fulfilled most of the requirements stated above, as well as certain others to be detailed presently, was the *Ro-ddu* seed area, at Aberdovey. At low water of spring tides, certainly, many areas bearing mussels are readily accessible, but in the majority of them the individuals are very unevenly distributed. It has been said before that the mussels with which we are chiefly concerned here are those from 2″ to $2\frac{1}{2}$″ in length, as, at Aberdovey, the average growth made by a two-inch mussel during the close season is about half an inch (actually $\frac{9}{16}$″).

Therefore, the conditions required in order to obtain this "population factor" were, not only the greatest number of individuals in, say, one square foot, but that all within such unit of measurement should be between 2″ and $2\frac{1}{2}$″ in length.

The sea mussel is fixed in a variety of ways (Fig. 3); if in clusters, the long (antero-posterior) axis may lie in any plane without inconveniencing the shellfish, and the same may be said of it when attached to stones and other solid objects. When, however, it is found living on sandy or muddy bottoms, and more especially when crowded together, or if any force of current is experienced, it generally lives with its anterior or "head" end buried in the substratum, the posterior, or siphonal end, projecting slightly above the surface. The mussel apparently favours these conditions, and I have noticed that newly transplanted mussels soon gather mud and sand around themselves, as described above. In sluggish streams especially, such a posture confers certain advantages with regard to feeding. The siphons will thus be slightly raised above the level of the floor, and, therefore, in a better position to receive the detritus and other food material which washes about there, than if they were more elevated. In this way, a bed of mussels will retard food particles passing through it.

This condition prevails on the *Ro-ddu* Scar, which is occasionally accessible at very low spring tides. By actual count of the individuals (all from 2″ to $2\frac{1}{2}$″ in length) falling within one square foot, I found that the population factor in this place lay somewhere between 121 (11 × 11) and 144 (12 × 12). These figures represent crowded, though not excessively crowded, conditions[1].

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[1] For details of overcrowded conditions on mussel beds, etc. see article by Andrew Scott and Thomas Baxter, "Mussel Transplantation at Morcambe," in the *Report* for 1905 of the Lancashire and Western Sea Fisheries Laboratory.

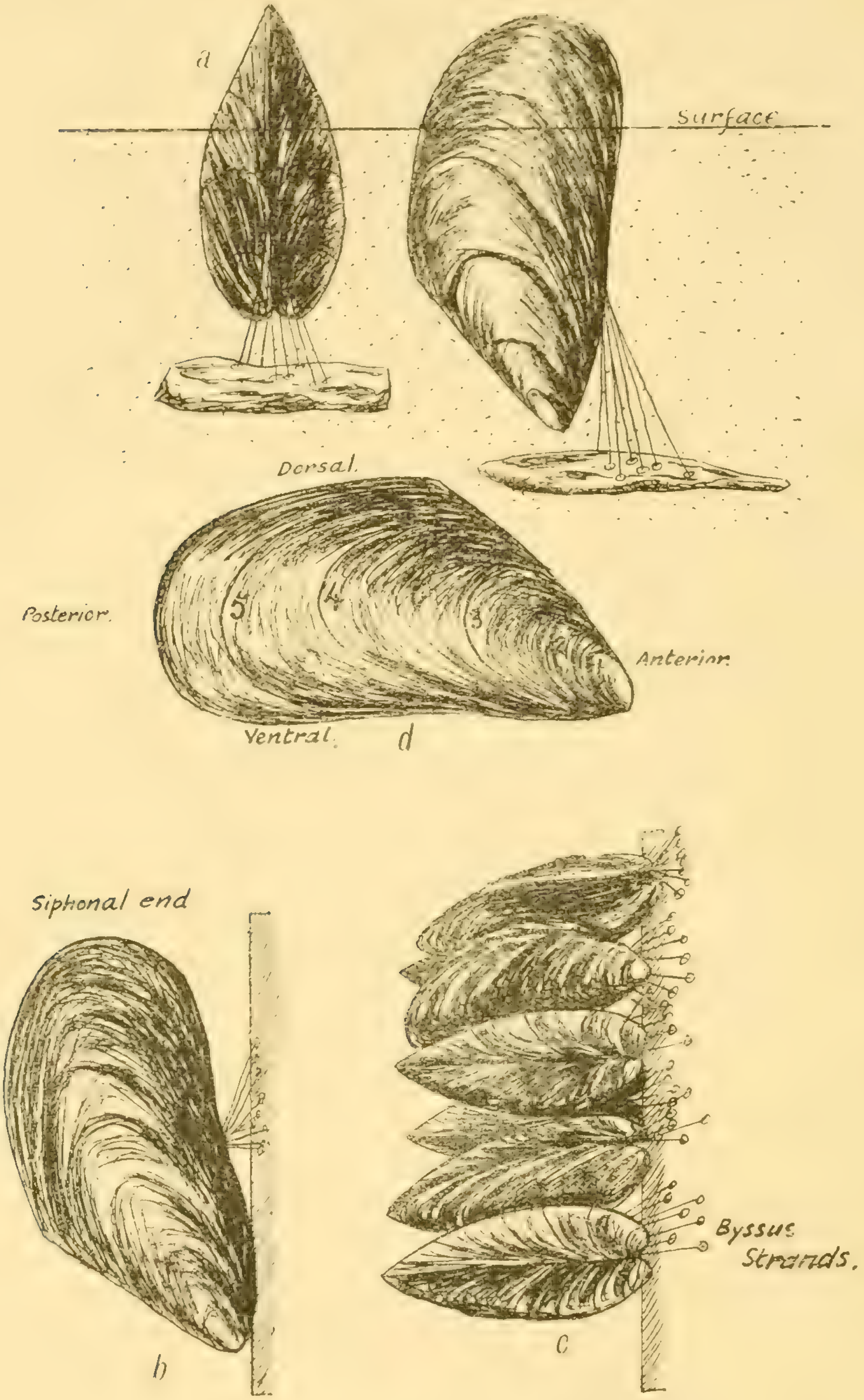
a
Surface
Dorsal.
Posterior.
5
4
3
Anterior.
Ventral.
d
Siphonal end
b
c
Byssus Strands.

Fig. 3. *Fixation of Mussels, Growth Marks, &c.*

a. Mode of anchorage in a muddy or sandy substratum exposed to currents. *b, c.* Mode of fixation to vertical surfaces,—solitary and crowded conditions. *d.* Mussel, with ridges on shell denoting its age. The thick numbered lines are "winter marks,"—therefore, the individual figured is five winters old. It is a "seed" mussel, from the *Ro-ddu* "Scar," Aberdovey. The right side (valve) is shown.

Can we, then, take this result as our ideal population factor, as it stands, and can this numerous population be expected to flourish? In order to determine this point, in view of what is known with regard to the abundant food supply available for the mussel, I conducted the following check experiment. A band of thin iron, 1½″ in depth, was bent into the shape of a square foot, in which were placed mussels, "head" end downwards, 2½″ in the vertical axis, until the measure was well filled. Sufficient space was allowed for each individual to function. They were then counted, and were found to number 121 (11 × 11) individuals. This result is in close agreement with the rougher totals obtained in natural conditions on the *Ro-ddu* seed bed. Therefore, such a number can live and thrive on the fishing grounds, and it may safely be taken as the population factor desired. The poor condition of the mussels on the seed beds is due to a special cause, or a combination of causes, which will be considered immediately.

Such a population obviously cannot be distributed homogeneously over the whole of the fishing grounds, but, even if portions of it have been too thickly restocked, a certain degree of readjustment will take place. The diatoms, and other organisms, vegetable detritus, etc., on which *Mytilus* feeds are present in practically inexhaustible quantity, and every individual in even a populous colony will be able to procure an ample supply of food material for its needs, unless, that is, badly overcrowded conditions cause the water currents to become obstructed in certain cases.

I have examined a large number of mussels from the seed areas (more especially those from *Ro-ddu* Scar, Aberdovey), as well as from the fishing grounds, at different seasons of the year, with regard to their stomach content. Some very interesting, and apparently contradictory facts were noted in this connection, but upon consideration, these will be found to be in accordance with the conditions in which the mussels live.

I have found, for instance, that the stomach content of the seed mussels (poorly fleshed mussels) is generally equal to, and sometimes greater than, that of individuals from the actual fishing grounds, although scientists and others have not hesitated to call the former starved individuals. Also, the organisms, etc., present were, if anything, in greater variety in the case of the mussels from the scars. This state of things needs some explanation, but this attempt to account for the poor flesh-content of the seed muscles must be regarded as tentative. As the beds at Aberdovey are very sharply defined, I confined these observations to this place, for the most part.

The Conditions of Life on the Scars or Seed Areas.

In his book, *Life in the Sea*[1], J. Johnstone, discussing the views of Pütter and others, suggests the possibility that the respiratory and other tissues of certain aquatic animals assist in the assimilation of certain foodstuffs held in solution in the medium in which they are bathed. That, in fact, it may be proved in the future that such tissues function as the chief means[2] in the nutrition of a large number of forms. In the same connection, he calls attention to the relatively large extent of the "so-called respiratory surface of the mollusc or ascidian...," both sedentary forms in which, as might be supposed, "the respiratory function is much less important than it is in the case of a warm blooded animal," because, in them, metabolism proceeds more slowly. He further discusses the possibility of the "anal respiration" of certain of the microcrustacea as being, partially at least, nutritive in character. This hypothesis is a fascinating one, but the experiments of Moore, Edie, and Whitley on the nutrition and metabolism of marine animals[3] seem to disprove Pütter's results. Lobsters (to mention one instance) were kept in seawater, which was regularly renewed, in tightly closed vessels. All plankton was removed from this water before it was introduced into the vessels. The lobsters lived as long as seven months under these conditions. At the end of this time, they frequently registered an increase in weight, but this was found to be due to what may be described shortly as a water-logging of the tissues. As an alternative explanation of the large respiratory surface shown by the types mentioned above (sedentary types), among others, the following suggestion is made. The rate of oxidation in many aquatic animals is very low, a fact which has received somewhat belated recognition. Yet, even so, a relatively large volume of water has to be treated by the organism in order to supply its needs. It is fairly certain that, for various reasons, feeding is often interrupted for longer or shorter periods. Therefore, the taking in of food must be so adapted as to allow of a reserve being accumulated to enable the organism to survive during periods when the supply is cut off. This would go far towards explaining the large respiratory surface in the forms under discussion, because in them (most Lamellibranchs, Ascidians, etc.) the cilia of the gill epithelium alone serve as the mechanism of the respiratory streams. A large gill-surface means that a larger volume of water can be treated by those forms possessing it.

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[1] Cambridge University Press.

[2] Others regard vegetable detritus as the most important element in the food of *Mytilus* and some other forms.

[3] See article in the *Report* for 1913 of the Lancs. and Western Sea Fisheries Laboratory: "The Nutrition and Metabolism of Marine Animals: the Rate of Oxidation and Output of Carbon-dioxide in Marine Animals in Relation to the Available Supply of Food in Sea-Water," by Professor Benjamin Moore, F.R.S., Edward S. Edie, B.Sc., and Edward Whitley, M.A.

Even if the validity of Pütter's theory of "osmotic" nutrition be fully conceded, it does not help us much to understand the poor flesh content of the seed mussels. It must be stated again that, as the *Ro-ddu* Scar is situated near the narrow neck of the estuary, and consequently all the water entering or leaving it has to pass over the bed, any such dissolved food material that may be present higher upstream will have to pass here on its way seaward.

Fouling of the Beds, etc.

The toxic effect of noxious matters liberated in the course of metabolism by large and crowded assemblages of animals,—products of excretion and metabolism,—must now be considered briefly. This factor may be taken as explaining, in some degree at least, the poor condition and high mortality of mussels in those beds which, besides being very crowded, are situated in a sluggish current, where waste products may remain and accumulate to the detriment of the population[1]. When the shellfish are several layers deep, such a condition of things will probably be intensified. On the *Ro-ddu* Scar, however, the animals, though very closely packed, are never overlain by their congeners. Because of this, in conjunction with the great tidal scour to which the place is subjected, the patches of mussels, and the sand in their vicinity, are always remarkably free of noxious substances. Mussel excreta may certainly be detected at times, but in quite negligible amount.

Food Material.

The plentiful and varied nature of the food in the stomach content of mussels from all situations (diatoms, protozoa, detritus, etc.) proves that there is no lack of suitable aliment. Each mussel (as has been explained), in the seed beds will have free access to the water currents, except in certain circumstances to be considered presently. The paucity of diatoms and other organisms, in material collected by means of the tow-net near the mussel beds, compares in an interesting manner with the stomach content of *Mytilus*, with its wealth of organisms. It must be borne in mind, however, that the greater number of diatoms, etc., entering the mouth of the tow-net, pass out again through the meshes of the silk or other fabric of which the net is fashioned. As the food supply is ample, we are forced to conclude that, for some reason, the individuals are not always able to avail themselves of it.

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[1] See article by R. L. Ascroft, "Mussel Beds and Mud Banks," in the *Report* for 1898 of the Lancs. and Western Sea Fisheries Laboratory.

Silting of the Beds.

It has been said in the foregoing that parts of the mussel nursery situated towards the Bar at Aberdovey appear to be always covered by sand to a greater or less depth,—not necessarily the same portions all the time. I have never visited this place without observing patches of it in this condition, the buried mussels lying beneath from one to about four inches of sand. As this place dries only at exceptionally low spring tides, when the volume of water entering and leaving the estuary is much greater than normal, we may infer that this "sanding" process is worse at such times than during neap tides. Surface tow-nettings, taken at various states of the tide, reveal the large amount of sand always carried in suspension by the current, both at Aberdovey and in the other estuaries. On the other hand, the sand probably remains longer over any given place during the lesser tides than during springs, when patches covered by one tide may be cleared by the next. The direction and force of the wind are other factors which have considerable influence in this silting process. From some preliminary (incomplete) experiments which I carried out at Aberdovey, under artificial conditions, during the summer of 1916, I found that mussels, despite all care, succumbed in from four to five days when covered by sand. Not only was this the case, but, with even the slightest covering of this material, the mussels made no effort whatever to raise themselves above it, or otherwise to free themselves. Yet a vigorous stream from the exhalent siphon would have cleared them, as the individuals were in a position favourable to such action. This dilemma seems to be one in which the foot might be employed with advantage if it is capable of being utilised as an aid to movement in the adult stage. I have not observed it to be used for this purpose, except in very small individuals, at any time. Although difficult of proof, I am inclined to the view that *Mytilus* behaves in a similar manner when covered by sand in natural conditions. That is, it remains passive, with its normal life processes slowed down, until the sand is removed by the current, or till death supervenes. Fishermen often assert that mussels are able to raise themselves above accumulating mud or sand by the lengthening of their byssus strands, which are attached to underlying stones and other substances. What really happens is that, as one generation dies and becomes buried (or, perhaps, becomes buried and dies), a new generation grows up, which anchors itself to the shells of its predecessors. So the bank grows, each successive generation accumulating more silt, and, in this manner, covering those beneath[1]. It is not improbable, however, that in natural conditions, it may survive for a somewhat longer period than that mentioned above. Whatever future research may prove to be the true facts, I am convinced that the above factors account, in a large degree, for the poor flesh content of those shellfish living on certain beds which are liable to silting. Covering by sand causes feeding to be interrupted, often for fairly extended periods, whereas, in better situations, it proceeds ceaselessly. There must be a considerable amount of sand held in suspension in the water near the bed of the river, and it is suggested that, often for some hours during each tide, this factor is serious enough to prevent the mussels feeding. They are compelled to remain closed in order to prevent the entrance of sand into the branchial cavity. The views expressed above receive a certain degree of confirmation (although perhaps this is not very definite) from the evidence afforded by the mussel's orientation with regard to the current, when this is a swift one. My curiosity and scepticism were aroused by the following paragraph, as my own experience had led to results opposed to the views stated by its author. In an inaugural address to the Malacological Society[2], B. B. Smith Woodward says: "*Mytilus*, which also comes of a family having a long pedigree, has not a particularly stout test capable of resisting heavy blows, but it meets the waves with its outwardly directed, sharp, wedge-shaped shell and cleaves them instead;...." On the *Ro-ddu* bed, however, where the mussels are buried head foremost in the sand in order to secure a holdfast, I found that, in the majority of cases, the valves, or sides, opposed the currents. Thus, one valve faces upstream, and the other downstream. In this manner, they are probably able to feed for rather longer periods than would be the case if they were placed as stated in the quotation, because of the sand danger. Mussels may, and do, meet the current with their sharp siphonal extremity, but this is probably because they have little choice in the matter, or because the velocity of the current is not great. The quotation is, without doubt, very misleading.

As *Mytilus* does not appear to thrive in purely marine conditions the more seaward (generally) situation of the seed areas may possibly be a factor to be considered in attempting to account for the light weight of their population. Remembering that the sea mussel is essentially a brackish water animal, it is probably safe to say that its "condition" varies with the difference of freshwater influence.

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[1] See also article by R. L. Ascroft, *op. cit.*

[2] "What Evolutionary Processes do the Mollusca Show?" *Proceedings of the Malacological Society*, Vol. VII, Part 5, June 1907.

Growth-Rate of the Sea-Mussel.

The growth-rate of *Mytilus* will be considered here mainly from the economic standpoint, leaving points of more purely scientific interest for another occasion. One point of general interest, and some importance, must be noticed in this place, namely the amount of growth made by *Mytilus* during the first year of its life, in its natural habitat. These observations were made on a suitable portion of the foreshore, near the fishing grounds, at Aberdovey, near low-water mark of spring tides, and they extended over a considerable period. Certain stones were carefully watched, as circumstances permitted, upon which mussel spat was likely to settle (the spawning time probably commences at the end of April, or during May). In due course, young *Mytili* were seen to have affixed themselves thereon, and in July of the following year (1917) they had attained a size varying from ¼″ to ½″.

During the course of transplantation work in Cardigan Bay, for two successive years, it has been found that a large proportion of the seed mussels measured about two inches in length. It was desired to ascertain the growth made by these during the close season, which, at Aberdovey and Barmouth, extends from April 1 to October 31 inclusive,—a period of seven months. At Portmadoc, the close season begins a month later, and ends a month earlier, than at the above named places.

Various means were tried of marking large numbers of two-inch mussels, as for instance, by the application of spots of specially prepared paint. This pigment not only hardened under water, and is known to have adhered for some considerable time to the shells, but it left the mussel so marked quite uninjured. The attrition of water-borne sand, however, removed all trace of it in the course of time, and to my disappointment, not a single marked mussel has been recovered from any of the beds. As a check experiment, some cages of galvanised iron wire were constructed at the same time, and these were deposited in the river at Barmouth. Some of them were recovered at the commencement of the next fishing season, and the surviving mussels were carefully measured. As the cages would seem to have been affected by the shifting sand that has lately covered portions of the Barmouth mussel beds, the results obtained are not of great value. Other cages, more carefully constructed, were placed in the river at Aberdovey, and have not yet been recovered. It is feared that a recent "creep" of the foreshore may have buried them.

Despite these setbacks, however, some valuable data has been amassed with regard to the growth of *Mytilus* during the close season. Upon removal from the poor areas (seed beds), the transplanted mussels make such rapid shell, as well as flesh growth, that usually a distinct ridge is formed on the shell, which marks off its older portion from the newer growth. When removed from a poor to a better situation, this mark is so definite and unmistakable, that it is impossible to doubt its meaning (Fig. 3). At the commencement of the fishing season (*i.e.* after the transplanted mussels had spent about seven months on the fishing beds), I examined a large number of individuals, which, from certain unmistakable indications, had been brought from the poorer situations. The average increase in length made by a two-inch mussel in this time was found to be rather more than half an inch (actually $\frac{9}{16}''$).

Growth Rate of the Sea Mussel.

Size of mussel	Locality	When transplanted	When recovered	Average increase in length	Length of growth period in days	Number examined
2″ (5·1 cm.)	*Ro-ddu* seed bed	March 30, 1916				Several hundreds
$2\frac{1}{2}''$ (6·4 cm.)	Near Literary Institute, Aberdovey		Nov. 15, 1916	$\frac{1}{2}''$ (actually $\frac{9}{16}''$)	231	Several hundreds

Now let us consider the increase in cubic content which this growth in length represents,—reckoning the latter at half an inch. The following figures were obtained by placing in water a large number of individuals (sometimes singly, sometimes more than one), in a partially filled measuring glass graduated in cubic centimetres. In each case, the valves were carefully tied with cotton to keep them in apposition, as any water entering them would have resulted in too low a reading. A number of shells were also treated in a similar manner, and the readings for them, being deducted from the total mass including the shells, give the correct figures for the valve content. This of course includes flesh, air, water, etc.

Average Cubic Content of Mytilus as measured by Water Displacement.

Size of mussel	Cubic content (including shell)	Displacement of shell only	Actual cubic content of valves	Increase	Length of growth period in days	Number examined
2″ (5·1 cm.)	10 c.c.	3·3 c.c.	6·7 c.c.			Several hundreds
2½″ (6·4 cm.)	22·5 c.c.	5·0 c.c.	17·5 c.c.	10·8 c.c.*	231	Several hundreds

* This represents an increase of, roughly, 161 %.

Weight Experiments.

A considerable number of mussels was utilised in the determination of the figures given below. The average weight probably varies considerably at different seasons of the year, and, during the summer months especially, I have found that mussels are often poorly fleshed and of light weight. They increase in weight in autumn and winter. The figures here represent the weights of fairly heavy, unspawned individuals.

Average Weight of Mussels in Shell (Live Weight).

Size of mussel	Weight (including shell	Locality	Date	Increase	Length of growth period in days	Number examined	Remarks
2″ (5·1 cm.)	14 gms.	*Ro-ddu* seed bed, Aberdovey	March 30, 1916			Several hundreds	Unspawned (fairly heavy) individuals
2½″ (6·4 cm.)	30 gms.	Fishing grounds, Aberdovey	Nov. 15, 1916	16 gms.*	231	Several hundreds	Fairly heavy mussels

* This represents an average increase in weight of about 114 %.

Average Weight of Soft Parts (Flesh Content).

In the case of a soft bodied creature like the sea mussel, which secretes an abundance of mucus, it will be understood that it is difficult or even impossible to determine accurately what is organic matter and what not, in the fresh condition. A rough method of estimating the flesh content is, therefore, of no use whatever. Special methods have to be employed, and these have to be followed with great care if the results are to prove of any value.

In order to determine the readings given below, a number of mussels of the required measurement were heated until they maintained a constant weight in an air oven at a temperature of 100° to 105° C. The shells and byssus fibres were of course removed. At the conclusion of the period of desiccation the weights of the residues were determined by a balance, and the average weight calculated.

I am greatly indebted to Dr T. Campbell James, of the Edward Davies Chemical Laboratory, U.C.W. Aberystwyth, who kindly worked out these results, and who is responsible for the figures given in the following table.

Average Dry Weight of Organic Matter (Flesh Content).

Size of mussel	Average weight of dry organic matter (flesh)	Locality	Date	Increase	Number examined	Remarks
2″ (5·1 cm.)	0·949 gms.	*Ro-ddu* seed bed, Aberdovey	Mid April, 1916		6	Unspawned mussels
2½″ (6·4 cm.)	2·027 gms.	Fishing grounds, Aberdovey	November, 1917	1·078* gms.	6	Heavy mussels

* Therefore, the approximate increase in flesh content made during the close season is 114 %.

The Maximum Potential (Ideal) Productivity of the Aberdovey Mussel Beds, and its Money Value.

At Aberdovey, theoretically, a "bag" of mussels, as packed for export, contains one hundred pounds of the shellfish. Actually, it weighs about 125 lbs. in order "to allow for the decrease of weight consequent on the loss of moisture during transit to the various market centres."

It was necessary to estimate, approximately, the number of mussels of different sizes contained in a bag of 125 lbs. In order to do this, several pounds of each of the sizes required were weighed, and the number per bag calculated from the figures so obtained.

We have seen already that 121 mussels each 2½″ in length can thrive in a space of one square foot. Let us assume that the Aberdovey beds are populated to this extent. We see that, in order to fill one bag with 2½″ mussels, the total population of nearly fourteen square feet is required. The estimated total area available for mussel culture at

Aberdovey is some 76,000 square feet[1], which, if stocked to its utmost capacity, would number a population of 9,196,000 individuals[2]. This number would suffice to fill, roughly, about 5659 bags.

Number of Mussels contained in a bag of 125 *lbs. as determined by weight.*

Size of mussel	Approximate no. per bag of 125 lbs.	Locality	Date	Number of lbs. weighed	Remarks
2″ (5·1 cm.)	3250 individuals	Wall at Penhelig, Aberdovey	July 19, 1917	8 lbs.	Old and thick-shelled mussels
2½″ (6·4 cm.)	1625 individuals	Wall at Penhelig, Aberdovey	July 19, 1917	6 lbs.	Old and thick-shelled mussels
2¾″ (7 cm.)	1312* individuals	Fishing grounds, Aberdovey	August 4, 1917	6 lbs.	Thin-shelled mussels

* This number is probably too high. The shells of these individuals were less thick and consequently lighter than those of the other sizes given. By actual count of the mussels (averaging about 2¾″) in a measure, three of which the fishermen count as one bag, I estimated that about 1100 individuals of this size went up to make a bag of 125 lbs.

The average price per bag received by the fishermen throughout the season may be taken at about five shillings,—sometimes rather less and often above. Therefore, taking this sum as the unit value per bag, the whole yield, as calculated above, should represent a value in money of something near £1414. 0*s*. 0*d*.[3]

If twenty men were regularly employed in the mussel fishery at Aberdovey throughout the fishing season of five months, counting this period as twenty weeks, this sum of money, if equally distributed, should mean that each man would earn a wage of £3. 10*s*. 0*d*. per week.

It must be admitted that such an intensive yield might prove impossible of realisation in practice, but the difficulties are not so insuperable as they appear on a casual consideration. Returns not very far short of the figures given above might reasonably be expected if the necessary amount of restocking is carried out with due care. A good deal of space would be occupied by individuals below the legal size, down to very minute mussels which have developed from the spat. These, however, would occupy the interstices between the larger mussels, to a considerable extent, and, at all events, the space which they occupy would be compensated by those larger mussels living in clusters, and by the increased superficial area of the ground resulting from inequalities in its surface.

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[1] This does not take into account walls, piles, etc., which afford a holdfast to hosts of mussels of all sizes.

[2] Thus, the progeny of a single female mussel, if all survived, would suffice to populate the entire fishing beds at Aberdovey! (see paragraph in another place).

[3] It is estimated that about thirty tons of mussels were *exported* from Aberdovey during the season 1916–17. At 5*s*. per bag, this represents a value of only £150. Had the demand held, a much greater quantity could have been marketed, and, therefore, the river is fairly well stocked for next season's fishing. Cooperation between the fishermen is the great need of the local mussel fishery.

Restocking the Beds (*Transplantation*).

We shall assume that, at the close of the fishing season, the beds have been exhausted of mussels of the legal size (two and a quarter inches, and above). It is now necessary to estimate the amount of transplantation requisite in order that the maximum yield may be maintained in the following autumn, and the distribution among the fishermen each his proper share in this work.

In the first place, it is necessary to gauge how far the beds are already stocked with mussels below the legal size, which have either not been brought up in the course of fishing, or else have been thrown back when the men cleaned their catches. This is a somewhat difficult matter, as obviously conditions will vary in different areas. Still, knowing something of the rapidity of the mussel's growth rate, it will probably not be very wide of the actual state of things if we assume that one-fourth of the area is intermittently stocked in this way. Therefore, three-fourths of the ground will need to be replenished by means of transplantation. This, at Aberdovey, represents some 57,000 square feet, and, if we aim at placing 121 individuals (in this case each of 2″ in length[1]), it involves the removal and deposition of 6,897,000 individuals. This number would fill, roughly, 2122 bags, and represents 106 tons of shellfish.

Most of the boats used in this fishery, at Aberdovey and elsewhere, are fairly large ones, each capable of carrying one ton or slightly over. This means that, if the maximum amount of transplantation is carried out, a boat, under the most favourable conditions, would need to make one hundred and six journeys with its maximum load of one ton[2] of seed mussels. A single boat could only procure this large cargo during a very low spring tide, when the seed bed dries, and the mussels are simply shovelled into it. If gathered by means of a rake, it would scarcely be possible for a single boat, with a crew of one, to procure more than half this quantity per tide. But if, as we have supposed to be the case, twenty men were working at the fishery, and that all of them assisted in the transplantation, removing one ton per tide per man, the whole amount could be removed in, roughly, ten journeys per boat.

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[1] As a 2″ mussel will increase to 2½″ in seven months, this growth has to be allowed for.

[2] This amount was often exceeded during the transplantation experiments at Aberdovey, even when the crew consisted of one person only.

The scar may be supposed to dry for about four or five days during low spring tides, or, even if it does not actually dry, the depth of water covering it will be negligible, and, therefore, the whole operation could be carried out in the space of two spring tides. If additional assistance were forthcoming, the time occupied would be further lessened. Thus boats from a neighbouring port might be requisitioned for a few days, their owners assisting; such services to be repaid in kind later. The mussels should be transplanted prior to spawning.

Some Destructive Influences, etc.

It has been mentioned before, that mussel beds, when affected by strong currents, are liable to much destruction through becoming undermined, when large masses become detached. These felted masses are swept out to sea and destroyed. The wastage of spat is simply incredible, if, indeed, it is to be regarded as wastage. Myriads of creatures feed upon the larvae, both in the brief free-swimming stage and after fixation. I believe that frost has been known to destroy large numbers of mussels in beds subject to its influence, but I am unable to quote any authority for this statement, at the moment. I have not remarked such an effect in Cardigan Bay.

The chief fish consumers of young mussels are those belonging to the Pleuronectid family,—Plaice, Dab and Flounder. Skate are caught near the seed areas at Aberdovey, and it is not unlikely that they feed upon the thin-shelled population of these areas.

Fishermen assert that Herring Gulls, Oyster Catchers, etc., favour a dietary of mussels, and, certainly, whenever the *Ro-ddu* area becomes dry, large numbers of these birds resort to it. Scott adduces evidence confirmatory of this statement, and found traces of mussels in gulls' excreta, while Field gives a list of birds feeding on mussels in America[1].

Several carnivorous molluscs attack the mussel, but the only one that need be mentioned here is the Dog Whelk (*Purpura lapillus* L.), which may sometimes be detected in the act. Mussel shells bearing a neatly drilled hole are not uncommonly found[2],—clear testimony of the attacks of a gastropod culprit.

[1] See article by I. A. Field in *The American Museum Journal*, October, 1916.

[2] *Ibid.*

In the branchial chamber of large mussels there is frequently present a small crab (*Pinnotheres pisum*). An examination of the stomach content of several of these crustacean "messmates" of *Mytilus* revealed the presence therein of the diatoms and other materials[1] utilisable by the mussel itself as food, but diverted by the crabs to their own use. I have remarked that it is never (or very rarely), found within the valves of the seed muscles, which, as we have seen, are poorly nourished. This is significant, because, as they are frequent in mussels from the fishing grounds, it would appear that the partnership is a profitable one from the crab's point of view. I have noticed that, in certain cases, where the female *Pinnotheres* had attained a relatively large size, it would seem to have exerted considerable pressure on portions of the mantle lobes, and upon the shell beneath. In some instances, this pressure had caused the nacreous or pearly layer to be dissolved away, probably by the action of pathogenic matters secreted by the cells of the mantle at the points affected. Thus, the presence of *Pinnotheres* (although it may not be parasitic in the strict meaning of the term), is probably more or less harmful to its host. By fishermen and dealers alike, *Balanus*-encrusted mussels are regarded with great disfavour, because, by rendering the appearance of the shellfish unsightly, their market value is considerably reduced. My own observations tend to show, however, that, so far from being an unmitigated nuisance near mussel-beds, *Balanus* may actually prove of some benefit to young mussels. The spat tends to settle (or, rather, to remain) on stones, etc., which are encrusted by numbers of *Balanus*, while other stones in the vicinity, although to all appearance equally suitable, are frequently barren. A *Balanus*-covered surface certainly offers a good attachment, and I have frequently remarked young *Mytili* growing up and thriving actually within the "parapet" of *Balanus*, the original tenant of which had died. I have no doubt that large numbers of larval *Mytili* receive their start in life through the agency of the *Balanus* colonies. The nauplius and cypris stages of *Balanus* larvae are not uncommonly present in the stomach content of *Mytilus*, and they probably form a not inconsiderable part of its food in spring and early summer. The Common Starfish (*Asterias rubens*, L.) is a notorious enemy of the mussel. It is occasionally found on the seed beds at Aberdovey, and elsewhere in Cardigan Bay, but, being anything but numerous in these situations, it cannot be classed as a serious pest.

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[1] *The Food Value of Sea Mussels*, by I. A. Field, Government Printing Office, Washington, U.S.A.

During my examination of the stomach content of *Mytilus*, I found that Nematodes were present in a large number of individuals. The matter is being investigated, and these thread worms may prove to be true parasites.

The above will suffice to show that, as regards animal foes, the amount of damage wrought in the Cardigan Bay mussel areas is inconsiderable. Indeed, their activities may be regarded as positively beneficial in their effects, inasmuch as they serve to thin the crowded population of the scars to some small extent.

C. L. Walton[1] has found that mussels adherent to vertical rock faces, piles, etc., break away and fall to the ground when they attain a length of 2½″ to 3¾″, and a weight in correspondence. It is suggested that this happens only where the mussels are subjected to frequent changes of medium, and not when always bathed in water.

Seaweed, when present in quantity near mussel beds, is often the cause of a high rate of mortality among the shellfish, which are apt to become smothered beneath masses of it. "Eel Grass" (*Zostera* sp.) and the commoner *Ulvae* may be cited in this connection. This source of danger, again, is rarely or never serious in Cardigan Bay.

Industrial pollution of rivers and estuaries may sometimes affect mussel beds in an adverse manner. At the present time, I am investigating the probable effects of plumbism on mussels from Aberystwyth Harbour, 99 % of which show a singularly uniform malformation in shell growth.

The greatest calamity to which mussel beds are subjected, however, is that of becoming silted over by shifting sand. Whole beds are often destroyed in this manner, as referred to in the foregoing.

Sand is also important in this connection in quite a different way. In August 1917, I received a sample of fairly large mussels from the entrance to the Harbour at Pwllheli. The shellfish were fairly well fleshed, but extraordinarily light in weight. This was owing to the fact that the attrition of water borne sand and shingle had worn away a large part of the two outer shell layers. Practically, only the innermost (pearly) layer remained to protect the animal at the anterior end, and, although this was relatively thick, it is improbable that, in such conditions, many individuals would survive for any great length of time.

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[1] *The Food Value of Sea Mussels*, by I. A. Field, Government Printing Office, Washington, U.S.A.

THE PORTMADOC MUSSEL BEDS.

Description of the Fishing Grounds.

The mussel beds at Portmadoc are situated in the River Glaslyn, near Portmadoc, and, lower down the river, at Borth-y-Gest, there are certain small mussel-bearing areas. The latter are not important at the present time, and need not be described here.

The chief beds lie (*a*) at Llyn bach (above the Ffestiniog railway bridge), (*b*) in the Dock, and, turning sharply in a north-easterly direction, the latter bed follows (*c*) the "gutter" or channel behind the New Quay. Scattered beds of small extent exist in the vicinity of the Slate Wharf and Ballast Bank, rather lower down stream.

The current here is comparatively tranquil, and, for the most part, the mussels maintain themselves on the substratum (mixed sand and mud) in bunches or clusters. The population in all the above areas is very abundant. Extensive seed beds adjoin the fishing grounds.

Acreage of the Portmadoc Mussel Beds, etc.

The figures given below were estimated from a large scale map of the district, and checked from my own knowledge of the fishing grounds. These occupy the more or less level bed of the river, and, therefore, it is not difficult to gain an approximate idea of their superficial area by such methods. This is, roughly, 400,000 square feet (rather above nine acres).

Assuming, as before, an ideal population of 121 mussels per square foot over the whole of this surface, we get the large total of 48,000,000 individuals ($2\frac{1}{2}''$ in length). This figure represents a total of 29,784 bags (approximately), and, in terms of money, a sum of £7446. 0*s*. 0*d*. Reckoning, as for Aberdovey, the amount of transplantation necessary to maintain this large production, we find that it involves the deposition of 554 tons (nearly). It would not be possible to procure this large amount of seed in Portmadoc itself, and, therefore, this factor might be regarded as governing the output of these beds. Near Pwllheli, however, there is a very large seed bed, the population of which is available to restock the Portmadoc fishing grounds, if necessary.

Should intensive myticulture ever be practised in this country, methods will have to be devised in order to increase the amount of space available for the settlement of spat. The plan of mapping out the many beds of poorly nourished mussels on various parts of the coast has been suggested. Some of these are fairly populous, and they exist wherever the influence of freshwater is felt, and there is suitable ground. These beds should be surveyed, and their population estimated, in order to be prepared for the possible failure of the usual sources of seed mussels. These small colonies are stocked automatically by the spat liberated by mussels in their vicinity, but more favourably situated. They represent a very small proportion of that which is washed out to sea and destroyed in various ways. They form a never failing, if not very considerable, source for the replenishment of the fishing grounds, which, by means of low stakes, or by diverting the stream to flow over a greater area of beach, could doubtless be considerably developed with a small outlay. This matter deserves serious attention. That the seed beds (generally more seaward in situation) may fail is no remote contingency, and such has been the case at Barmouth during 1916 and 1917. The winter storms and spring floods have resulted in serious damage being done to the beds, and several years may elapse before they regain their former dense population.

The Barmouth Mussel Fishery.

With regard to Barmouth and its mussel fishery, only a few words can be said in this place. The beds are of small extent, and always covered by a considerable depth of water. Since they are also situated on steeply shelving banks, their area is difficult to estimate exactly. If well stocked, they might give a maximum yield of mussels to the value of £300 or £400. These figures, however, are not based upon actual calculations, but, when all the factors are taken into consideration, they are probably not very wide of the potential production.

Purification of Mussels.

Most (and probably all) of the rivers and estuaries of Great Britain suffer from sewage and industrial pollution, in varying degrees. Sewers and drains empty into them, and also the effluents from factories and works on their banks. The sewage is often permitted to escape in an untreated condition, and this is the state of affairs that prevails in the Cardigan Bay estuaries, which, on the other hand, suffer very little from industrial waste products. This condition of things is obviously very unsatisfactory when considered in relation with the mussel beds, and extensive bacteriological analyses of water taken in relation with the fishing grounds reveal the presence of bacteria resembling those found in the human colon (*Bacillus coli communis* etc.), often in numbers too great to be ignored. Mussels may also contain through inhibition of contaminated water, "*Bacillus typhosus* (producing enteric fever), and, possibly *B. enteritidis* (producing Gaertner poisoning)." These last are, luckily, much more rare in this connection. Even though we need not place implicit trust in the findings of bacteriological science, which has to rely upon indirect methods or reactions in its determinations of these minute organisms, yet we see that the matter is serious enough. It is probable that (admitting the validity of their identification), their sojourn in the mussels' digestive tract, or in salt or brackish water, may have so changed the character of the bacteria as to render them generally harmless to man, or, at least, less harmful.

It will be remembered that, in a previous paragraph, it was stated that the water in the Cardigan Bay estuaries was never wholly changed in any one tide. Thus, impurities washing about in the river bed may remain there for a considerable time, and the significance of this factor now becomes apparent. Under such conditions (which affect the areas now being discussed), the occurrence of, for example, a single case of enteric, could bring about an immediate cessation of the fishing in the place affected. Therefore, it becomes necessary to effect the purification of the shellfish in order to safeguard the industry, no less than in the interests of the public health.

A crude method of "purification" is sometimes practised by the fishermen at certain places. After cleaning ("spinning") the mussels, they are placed in bags, which are left to wash for a day or two in the tide, where the water bathing them is known to be reasonably free from contamination. This rough method cannot be said to have the desired effect, for reasons now to be stated. According to recent views, any bacteria which the mussel may harbour are present in the animal's rectum; that is, in the faecal matter not yet extruded by the animal. Now, although mussels treated in the manner described above will speedily excrete such waste products, these, being retained by the closely woven fabric of the sacking, only serve to re-infect the shellfish.

Mussel purification tanks are projected to be erected (one is already in use at Barmouth), in connection with the Cardigan Bay mussel beds, under the supervision of the Lancashire and Western Sea Fisheries Committee. They are solidly built concrete structures, in several compartments, on the wooden grids on the floor of which the mussels are placed, in layers not exceeding three deep. They are designed to fill over the top at about high water of neap tides, when the mussels will rest under a depth of about two feet of clean sea water. As the faecal matter is ejected, it falls through the gratings on to the cemented floor beneath, which slopes away to outlet pipes of large diameter. The water is allowed to escape when the tide is low, and carries, as it flows out, the excretory products. Exhaustive tests (bacteriological and others) are carried out before the site of the tank is decided upon, in order to ensure the purity of the water gaining access to it. The shellfish remain in the structure for the space of forty-eight hours, and they are then put into bags bearing the lead seal of the Committee, to show that they have undergone treatment.

Another method, now being experimented with in this country, employs certain chemical substances, which cause the mussels to eject speedily all waste matters, and at the same time sterilises the water.

The capacity of these structures is limited to present day needs, and, therefore, if the industry is to be developed to its utmost limit, as outlined in the present article, these purification arrangements must be so designed as to expand with it.

In this article, it has been attempted to show the means whereby suitable "ground" in estuaries may be made to produce a greatly increased yield of mussels. Great efforts are being made in the U.S.A. to popularise this shellfish as an article of food, in view of its high nutritive value. In Europe, no such efforts are required, as its value has long been recognised. It is hoped that representative persons living in settlements where mussels are fished regularly will take up the matter, and encourage the fishermen to keep the beds well stocked,—work well worth the doing, from the standpoint of food production as well as in other ways. In the small seaside communities of Cardigan Bay, for instance, the mussel fishery forms practically the sole source of income to a fair number of men, who would otherwise be unemployed for long periods during which there is no other work for them to do. In these places, however, the industry, which has been shown to be capable of very considerable development, suffers because of the utter lack of cooperation between its members, and means must be devised to overcome this evil. A frequent cause for complaint by the fishermen is that they have no security of tenure, which however seems unavoidable. They ask to be granted the leasehold of portions of the beds, in which case, they assert, they would undertake to keep their respective "small holdings" stocked to their fullest capacity. This is open to objection, however, even were it possible to accede to their wishes. Most of our

British mussel beds are liable to much destruction from time to time. through silting and other causes. Thus, the leasing of portions of the mussel beds would simply give cause for further dissatisfaction. Co-operation between themselves, on the other hand, and their prior claim to the limited accommodation afforded by the mussel-cleansing tanks, would render their molestation by outsiders an impossibility. At the present time, most fishermen (on the west coast of Wales, at least), cannot be made to realise that regularity of supply creates a steady market.

I have now to thank those gentlemen who have kindly assisted me during the progress of the work, and in the preparation of this paper. I am greatly indebted to Dr J. Travis Jenkins, the Superintendent of the Lancashire and Western Sea Fisheries Committee, for much advice and assistance. Mr W. E. Whitehouse, and Mr C. L. Walton, both of the U.C.W. Aberystwyth, have also greatly assisted me in many ways. I have to thank Captain Enoch Lewis, of Aberdovey, for allowing me the use of a room as a laboratory.

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(See also text and notes).

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USTULINA ZONATA (LEV.) SACC. ON *HEVEA BRASILIENSIS*

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(With Plates III—VIII and 1 Text-figure.)

INTRODUCTION.

Pests and diseases on rubber plantations have caused little anxiety up to date. Scares due to attacks by *Fomes lignosus* (Klotzsch) and White ants (*Termes gestroi*) were prevalent before 1908, but in the general management of Malayan plantations pests and diseases have been considered a minor detail. There are certain estates where preventive measures had to be undertaken because of specific "White ant" or "Fomes" attacks, but these areas are strictly localised. Up to date, no general scheme for combating pests and diseases on rubber plantations could be put forward, for the trees have been extraordinarily free from insect and fungus troubles. Investigations carried out over the last two years indicate that more attention, especially to fungus diseases, will be necessary in the future. A general scheme of treatment may now be recommended with an assurance that money spent on routine disease work will be amply repaid.

HISTORY OF PESTS AND DISEASES ON THE PLANTATIONS.

The pioneer rubber planters in Malaya mostly obtained their experience on the tea and coffee plantations in Ceylon and the tea plantations of India. The failure of the coffee crop in Ceylon owing to the attacks of *Hemileia vastatrix* left a lasting impression, and in the early days of rubber planting, planters were inclined to believe many exaggerated reports of damage caused by various agencies. The root disease caused by *Fomes lignosus* (Klotzsch) was at first regarded as a potential exterminator of young rubber; about the same time the F. M. S. Government offered a $5000 reward for the best cure for "White ant" attacks.

This money was never awarded. Experience taught that "Fomes" attacks, even in the worst affected places where it may cause heavy losses, could be treated, and that attacks by White ants created little material difference in the long run on the majority of plantations. After these scares, a period of indifference to rubber pests and diseases set in until 1912, when the rapidity of spread of "Pink disease" throughout the peninsula stimulated enquiry into the necessity for vigorous treatment. The work of Rant (7) and Brooks and Sharples (2) proved the incidence of the disease and the probable causes of spread, and vigorous preventive measures based upon the work mentioned showed that "Pink disease" could be controlled by concerted effort. Since this time, a large number of plantations have passed the ten years stage and many of the old trees have been killed by fungi attacking the roots. The symptoms have been classed under various headings by Malayan planters i.e. "Wet-feet," "Brown-root disease," "Dry-rot," etc. As a result of work carried out over the last two years these general terms can now be assigned to specific fungi. This contribution deals with the dry collar-rot on old rubber caused by *Ustulina zonata* (Lev.) Sacc.

HISTORY OF DRY COLLAR-ROT.

Brooks (1) in 1915 made the first important contribution to our knowledge on the subject of *U. zonata* as a fungus causing a root disease of plantation rubber. Previous to this, Massee (3) in 1910 published photographs and a description of a fungus, *Eutypa caulivora* (Mass.) growing on a dead tree of *Hevea brasiliensis,* taken from the Singapore Botanic Garden by Mr H. N. Ridley. The photograph of the diseased wood shows the typical symptoms of a tree attacked by *Ustulina zonata.* It is probable this fungus was responsible for the death of the tree, *E. caulivora* growing as a saprophyte on the dead tissue. Numerous saprophytic fungi are always to be found on trees killed by *U. zonata* which are in an advanced state of decay. Petch (4) in 1910 records a case of *U. zonata* growing on an old *Hevea* which had died of root disease, and states that "apparently the disease was caused by this fungus, though the evidence was rather doubtful." Later in 1914 he says (5) "This fungus is a common cause of root disease (*i.e.* of Tea) in Ceylon, though not on Hevea." He records several cases of *U. zonata* on *Hevea brasiliensis* in fields where the trees have been planted among tea which has subsequently been allowed to die out. In 1916 Reeves (8), the Mycologist to the Rubber Growers' Association in Ceylon, published some observations on *U. zonata* with reference to rubber trees, and found the disease common in Ceylon.

There is, as yet, no report of this fungus being found on rubber in Java or in Sumatra.

Brooks obtained the fructifications and as a result of his observations established *U. zonata* as the cause of a collar-rot on *H. brasiliensis*. An account of his observations in Malaya up to the end of 1914 is given (1) when he left for England. At the beginning of 1915 specimens were obtained which necessitated a more complete investigation. This work was carried on through 1915–1916 and various side issues are still under consideration. A general account (10) on economic lines was published in 1916; the following article includes all observations made since 1914 up to the present date.

Petch (5) records several hosts for the fungus: Tea, *Cassia Nodosa, Benya ammomilla, Casuarina montana, Molia Dubra, Lafoensia Vandelliana, Denis Robusta, Citrus Decumana, Albizzia Molluccana*, and *Grevillea* sp.

FIELD OBSERVATIONS ON DRY-ROT AND COLLAR-ROT.

In Malaya, the disease is found on old plantations in every part of the peninsula; the fungus is not localised in its distribution as is the case with *Fomes lignosus* (Klotzsch). It attacks old rubber trees in the region of the collar; only in advanced cases does the fungus spread up the stem, and it seldom reaches more than three or four feet above soil level. In one case, however, the fungus has been found travelling from the collar up through the heartwood of the stem into the lower branches, some twelve feet high: externally the tissues appeared healthy except for about two feet above soil level. The fungus travels down through the heartwood of the lateral roots in the same way. The diseased wood in an advanced case is found to be dry and tindery, like touchwood, and running through the diseased tissues conspicuous black lines are to be seen. When the bark is removed, these black lines can be observed in some cases on the outer surface of the wood and, if the lines are followed carefully, it will be seen that they form thin plates of black tissue inside the wood, the edges showing as black lines on the exterior. A longitudinal section taken through the collar of a diseased tree shows these black lines running irregularly in the rotting tissues, often forming circles surrounding dark coloured patches of diseased wood (Pl. III, fig. 1).

There is no external mycelium associated with roots suffering from this disease, though fan-shaped, white patches of a felt-like mycelium may sometimes be observed on the exterior of the wood when the bark is removed. The absence of external strands of mycelium distinguishes this disease from that caused by *Fomes lignosus*, while the black, rhizomorphic strands between the bark and wood of trees attacked by *Sphaerostilbe repens* serve to distinguish those affected by this fungus. The typical dry-rot in the collar caused by *Ustulina zonata* cannot be mistaken, the wood in advanced cases falling to pieces under the pressure of the fingers.

This root disease is common on most of the older plantations in the F. M. S. though its presence is unsuspected. The fungus works slowly and insidiously, the crown of leaves becoming thin as it progresses in the collar. The diseased tissue is usually confined to one side of the collar, and from this side latex cannot be obtained. The opposite side may give a good yield and tapping is continued till the amount of latex obtained begins to diminish. When this stage is reached the tree soon dies and has to be taken out.

The dry collar-rot has been found occasionally on trees 5–8 years old, but it is only typically developed on trees over 10 years of age. A large number of magnificent trees in the older properties have been killed by this fungus. Cases are quoted later where large areas have been rendered useless owing to attacks by *Ustulina zonata* and other root fungi.

Fructifications are found on diseased roots, usually near soil level. They are closely adpressed to the stem; when young the flat plate-like fructifications are soft, rather leathery, whitish in colour and greenish-white at the edges. Later they darken and become brittle and closely resemble exuded patches of coagulated latex attached to the stem, which have blackened owing to exposure and oxidation. In this condition they are easily overlooked. When the fructifications develop near ground level, they are often difficult to detect as they become splashed with mud after a shower of rain.

OBSERVATIONS IN FIELD ON RELATION BETWEEN SHOT-HOLE BORER (*XYLEBORUS PARVULUS*) AND *USTULINA ZONATA*.

In the report of the Director of Agriculture, F. M. S. for 1914, H. C. Pratt, Government Entomologist, writes:

"*Xyleborus parvulus*. This beetle was first noticed in this country as attacking rubber in 1909. It occurred only in one district. The instance was undoubtedly due to the pollarding of a large number of trees. Many of these pollarded trees were attacked, and in a few cases adjacent trees which had not been pollarded were bored. Since that time this district has always lost a few trees each year from what would appear to be the attacks of this insect. During 1914 there was a remarkable increase in the number of cases reported to the Department of Agriculture, and there has been a corresponding increase in the districts in which it now occurs. It is instructive to find that all estates which are affected were either thinning-out the number of trees to the acre or had just finished this work."

The practice of planting trees to the number of 150–200 an acre on rubber plantations renders necessary the cutting out of large numbers when they reach the age of 6–7 years. During the thinning, attacks by boring beetles on the permanent trees become prevalent. Early in 1915 a living specimen of a rubber tree attacked by borers was obtained. This specimen (*A*) showed the insects active along one side of the stem extending from three feet above ground level to a height of twelve feet. The roots were healthy. Sections through the attacked parts showed that the borers were penetrating through rotten wood. Running irregularly through the rotten wood were black lines very similar to those observed in a typical case of dry collar-rot (Pl. III, figs. 3 and 4).

Immature fructifications of an *Ustulina* sp. were obtained on the surface of the attacked parts. On a neighbouring dead tree (*B*) attacked by borers, typical specimens of *Ustulina* fructifications bearing a conidial layer were observed in various stages of growth upon the bark; in close proximity numerous saprophytic fungi were growing. Sections of this tree showed more advanced symptoms than those found in specimen (*A*): these symptoms were identical with those found in the dry collar-rot of *Hevea brasiliensis* caused by *U. zonata*. A fungus was isolated from the affected wood in specimen (*A*) which proved to be practically identical with cultures established from typical dry collar-rot trees.

It would appear from the above that there is some connection between *U. zonata* and attacks by boring beetles. Much evidence to support a close connection can be advanced. Several estates in the F. M. S. were troubled during 1915 with leaf fires. Owing to a heavy wintering the leaves formed a layer several inches thick on the ground, and when dry the leaves are easily fired. In the areas through which the fires passed the bark of the trees was scorched and boring beetles quickly entered, though the latex streamed freely. On one estate, every tree in a nine-acre block of rubber, nine years old, had to be removed; four other estates encountered the same trouble on a smaller scale. In every tree entered by the borers the same symptoms described for specimen (*A*) were observed; the insects were penetrating actively a rotting portion of the wood through which black lines ran irregularly. Some time was spent trying to find scorched trees attacked by the fungus only. Specimens were obtained showing but five or six boreholes and the fungus working actively in the wood, but no case was found where borers were entirely absent. In the great majority of the trees, the association of insect and fungus was very pronounced. The fungus was carefully isolated from several of these trees and was identical with the cultures obtained from specimen (*A*).

Further supporting evidence for the connection between *Ustulina zonata* and attacks by boring beetles was obtained in an experiment described(9). In this experiment the bark of twenty-four rubber trees was scraped in order to see whether this treatment rendered them more liable to insect and fungus attacks. The laticiferous system was not injured in any way, the scraping being performed to compare heavy scraping—the cork-cambium being removed—and light scraping—the cork-cambium being left intact as far as possible. Five trees of the total treated were quickly attacked, three by borers. Two of the three trees attacked by borers showed traces of *Ustulina zonata* in the bark five weeks after the insects entered. In one tree, the fungus made beautiful progress and daily observations were made. An interesting point is that the borers disappeared after the first fortnight and the rate of growth of the fungus in the wood of the stem and collar could be directly compared. Pl. IV, fig. 5 is a photograph taken four days after the trees were scraped and shows the latex streaming down the trunk from the holes made by the beetles. Fig. 6 shows the surface of the wood exposed with the typical black lines formed by the fungus. Pl. VIII, fig. 21 shows a section through the diseased part six months after the scraping, and a comparison with Pl. VII, fig. 19, which represents a typical artificial inoculation at the collar about six months old, shows that the rate of growth of the fungus in the stem and collar is almost the same.

This experiment(9) indicates that the important protective layer in rubber trees is the outer layer of corky cells, and if this layer is injured, they are liable to attack by boring beetles. The laticiferous layer affords comparatively little protection against borer attacks beyond preventing the entry of the first few insects. The first comers trying to enter were trapped in the streaming latex, but later arrivals succeeded in entering through places prepared by their predecessors. On the estates troubled with leaf fires the scorching of the bark did not interfere with the presumed protective function of the laticiferous system of the trees, for the latex streamed freely from the holes made by the borers.

The above evidence affords a convincing explanation of the prevalence of borer attacks at the time of thinning out. When a tree is felled its branches come in contact with and bruise the branches and trunks of neighbouring trees, wounding the outer corky layers. Through these places boring beetles enter and the fungus *U. zonata* may be taken in by, or quickly follows the insects. The fungus penetrates the wood quickly, for the insects bore to every part of the tree carrying small pieces of diseased tissue, so setting up innumerable centres of infection. The fructifications form on the surface of the diseased parts, and spores from these are blown about the plantation. The rubber logs and stumps lying about the thinned-out areas form suitable growing places, as does any rotting soft-wood timber, and thus the fungus obtains suitable conditions for perpetuation and spread.

When a tree attacked by borers is examined, the typical symptoms caused by *U. zonata* can nearly always be demonstrated. The association is probably due to the fact that a tree penetrated by borers is very liable to attack from common wound-fungi. *Ustulina zonata* is a wound parasite on *Hevea brasiliensis*, and is also one of the commonest causes of rotting in soft-wood timber in the plantations. Its prevalence on the plantations in rotting timber and stumps increases its chances of attacking rubber trees whenever a suitable opportunity occurs. The fungus often gains an entry through wounds caused by the breaking of large branches. In these cases, there is always a copious exudation of latex for a lengthy period as fresh areas of healthy bark are attacked during the progress of the fungus. It passes much more quickly through the wood than the bark. It would appear that *Ustulina zonata* does not easily attack rubber trees unless an exposed wood surface, or a convenient path to a wood surface, as in trees penetrated by borers, is provided.

Fructifications are found on all parts of the stem and branches where the fungus is working in the tissues. "Stag's head" in rubber trees is a well-known phenomenon and is usually attributed to *Diplodia* sp., the cause of "Die-back." On two occasions the fruit-bodies of *U. zonata* have been observed growing on these dead branches taken from the topmost parts of the tree. When the fungus gains an entry through wounds caused by the breaking of large branches, a large quantity of fruit is usually produced about the place of entry; the later blackened stage of the fructifications are often masked by a copious exudation of latex from the diseased portions.

It is possible that borers may directly transfer spores to the trees they enter. Insects such as White ants, Red ants, etc. walking over the flat plate-like fruit-bodies when the latter are producing spores would carry away numerous conidia or ascopores attached to their appendages. Fructifications in the conidial stage have been found showing traces of insect markings; whether the latter were feeding on the spores is doubtful, but it was obvious they had spent some time upon the surface, judging from the intricate tracings.

Several cases of old trees hollowed by White ants and attacked by the fungus have been found (Pl.IV, fig. 8). These trees were all twelve years old; some had been successfully treated with the White-ant pumping machine at the age of eight years. The number of trees found attacked by White ants and *U. zonata* is comparatively small when compared with those attacked by boring beetles and *U. zonata,* or the number of old trees suffering only from the fungus attack. In a consideration of treatment and spread of the fungus, the White ant question appears to be of minor importance.

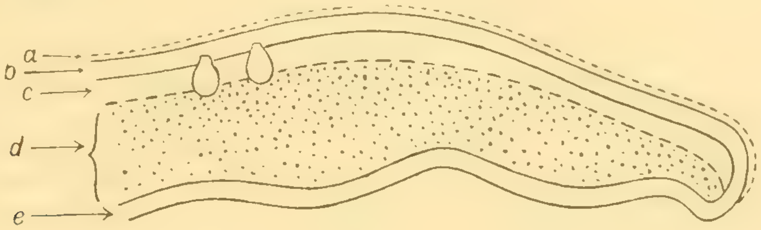
DESCRIPTION OF THE FUNGUS.

The development of the fruit-bodies of *U. zonata* has been carefully studied in the laboratory. Brooks' (1) description of Malayan specimens is incomplete because up to the time of his departure he had not seen the fructifications in the early stages. It may be stated here that the Malayan specimens correspond in every respect to the description given by Petch (4) for those of Ceylon.

The common fructification commences as a small yellowish-white plate closely adpressed to the bark. The plate increases in size and the surface darkens to a greenish-grey colour. This change in colour is due to the formation of a thick conidial layer. In the Laboratory this stage persists for about a week, and during this period the stroma is soft and easily cut. Owing to the disappearance of the conidial layer, the stroma becomes darker; as it ages it takes on a leathery consistency and ultimately becomes quite brittle and black. Typical young specimens in the field show a well-defined zoning on the surface (Pl. IV, fig. 7 and Pl. V, fig. 9) but those developed in the Laboratory did not show a conspicuously zoned surface. When fully developed the plate-like fructifications are several inches in diameter. A number of these plates may fuse together; large plates formed by fusion of smaller ones have been found covering an area of the stem three feet in length and nine inches broad.

When the flat plate-like fructifications are broken across, the tissues are found to be arranged in distinct layers. The accompanying diagram (after Brooks) illustrates the different layers.

On the upper surface (*a*) represents the remains of the conidial layer. Brooks did not observe the conidial layer in the specimens obtained by him in Malaya, though it appears a constant feature. It is very transitory as observed in the Laboratory; 4–5 days is the actual time between its appearance and the dispersal of the spores. (*b*) is the upper black zone, composed of compact tissue very similar to that composing the black lines, as seen in a diseased collar. (*c*) is a white loosely compacted zone in which the globular perithecia are formed. (*d*) is a broader band, grey in colour and leathery in consistency. (*e*) is the black zone on the under surface, which is continuous at the margins with the black zone towards the upper surface.



The globose perithecia communicate with the exterior by very narrow channels. The first formed elements of the perithecia can be recognised in suitably stained sections very early in the development of the fructification, long before the production of conidia. These elements stain more deeply with protoplasmic stains than surrounding ones and appear as small circular patches of spirally running hyphae.

In the early stages of development, the black zone is not present in the fructification. Whilst the stroma is still soft and yellowish, the walls of patches of cells of the loosely compacted layer, irregularly distributed, but at the same depth, become impregnated with carbonaceous material. Later, the walls of the cells of the loosely compacted layer intervening between the black patches become impregnated with similar material, their cell contents darken, and a continuous black, brittle zone is formed. It is a very characteristic zone, and can be used as a rough diagnostic feature when studying the variable forms of fructifications produced by this fungus. This zone is always present in the "Xylaria" forms of the fungus; many true *Xylarias* are found on rubber trees killed by *U. zonata*, but these do not show the black carbonaceous zone to which the fructification of *U. zonata* owes its brittleness. The greenish-grey conidial layer is formed about the time the black zone is completed, while the fructification is still rather soft and leathery. In many cases observed, the conidial layer is restricted to the younger, growing edges of the fructification, while the older parts in the middle are showing the ostioles of the perithecia. The hyaline conidia are abstricted abundantly from the apices of hyaline hyphae compacted to form a smooth surface. They measure four microns by two.

The perithecial openings can be observed as minute black spots almost immediately after the disappearance of the conidial layer. By this time the black zone is continuous, and the spore chambers are developed just below this zone in the more loosely compacted tissue. The asci are numerous, with paraphyses. The ascospores, when first delimited from the remainder of the protoplasm in the ascus, are hyaline, with no special contents. Later, they darken, become almost black, with two or three oil drops. They are slightly curved, inequilateral and lie to end in the ascus. The ascospores are 28–32 microns by 7–10 microns. They exude through the openings of the perithecia under moist conditions, looking like small drops of ink. When the amount of moisture fails, the exuded spore masses spread out over the surface, resembling black patches of dust surrounding the perithecial openings. Only on one occasion did the ascospores germinate readily; these were obtained immediately after extrusion from a fructification developed in the laboratory. Placed in potato mush agar in damp chambers they germinated in twenty-four hours, several germ tubes being put out along the side of the spore, none from the ends. The tubes grow vigorously and branch profusely.

The conidia germinate more easily, but do not produce a copious mycelium on potato mush agar in damp chambers. Conidia placed directly on slants, however, produce just as vigorous a mycelium as is formed from sowings of ascospores. Cultures are not easy to obtain from spores developed in the field, though the fungus can nearly always be obtained in pure culture from the black lines formed in the diseased tissue.

There is as much variety in the form of the specimens from Malaya as in those from Ceylon described by Petch. There is a solitary stalked form (Pl. V, fig. 11), the conidial layer being produced only on the top and continued a short distance down the sides. In some cases, these stalked forms may be aggregated to form a compact plate, the heads of the stalks becoming hexagonal in shape owing to mutual pressure. This approximates to the typical Kretschmaria form, the common *Kretschmaria coenopus* (Fr.) closely resembling this form of *U. zonata*, but the ascospores of the latter are much larger. There is another form which has not yet been found to produce spores; this closely resembles a foliose lichen (Pl. VI, fig. 14). Pl. V, fig. 10 shows a photograph of a fructification with the lichenoid type at the edges, gradually passing into the plate-like form with hexagonal heads; the commoner flat plate-like form was growing up from beneath the stalked form. In the photograph the growing over the stalked form masks the presence of the commoner form.

CULTURE EXPERIMENTS.

The *Ustulina* fructifications found on specimen (*B*) differed from those previously found in the F. M. S., for a typical conidial layer was formed as in specimens described from other countries. A further difference was observed, for the fungus attacking the wood in specimen (*A*) was isolated and the pure cultures lacked the typical zoning (Pl. VI, fig. 17 A) of those obtained by the isolation of the fungus from the rotting tissues at the collar. Again the bored trees showing this fungus were killed very quickly while the collar-rot proceeds very slowly.

Owing to these differences, critical cultural experiments were undertaken to decide whether there were two distinct species of *Ustulina* capable of attacking rubber, *Ustulina zonata* causing a collar-rot and another species distinct from, but closely related to *Ustulina zonata*, causing a stem-rot in conjunction with boring beetles.

TYPICAL CULTURES OBTAINED FROM COLLAR-ROT.

Pure cultures were first established after numerous failures by taking a small portion of one of the black lines from the collar under sterile conditions and placing it on a block of sterilised *Hevea* wood in a culture tube. Several days after sowing a greyish mycelium began to grow and spread out slowly over the surface of the block, remaining closely adpressed. As the growth continues, the mycelium turns black, forming a thin crust. If the cultures are allowed to develop for several weeks and the blocks taken out and cut open, black lines similar to those formed in the tissues in cases of collar-rot are seen in the middle (Pl. VIII, fig. 23).

Small pieces of the black crust from the wood blocks were taken and used to inoculate flask cultures of potato mush agar. A white flocculent mycelium first developed; after three or four weeks the surface of the jelly was covered with a black crust similar to that developed over the wood blocks. The crusts in these cultures showed a typical zonation, dark and light zones being formed owing to a thicker aggregation of hyphae at one part than another.

CULTURES OBTAINED FROM STEM OF SPECIMEN (*A*).

A description of symptoms shown by this specimen is given above. The trunk of the tree was sent into the Laboratory and the affected portion cut into sections. The boundary between diseased and healthy wood was well marked by a diffuse brown discoloration, and after twenty-four hours in the Laboratory, a copious white mycelium appeared at this junction. Pieces of this mycelium used to inoculate flask cultures of potato agar gave rise to cultures which, except for the absence of zoning, corresponded to those obtained from the collar-rot caused by *Ustulina zonata.*

Other cultures were started by placing small portions of the black lines developed in the rotten portions of the wood in sterile damp chambers. In two days hyphae began to grow out; after four days the small pieces of diseased tissue with the attached mycelium were taken and placed in flask cultures; similar non-zoned cultures to the ones described were ultimately obtained.

The boreholes made by the insects through the rotten wood were filled with fungus mycelium. Small portions were taken to inoculate other flasks and again non-zoned cultures resulted.

The non-zoned cultures are characterised by a peculiar folding of the crust which forms on the surface, due to unequal growth in different directions. This folding is seen especially well when the culture medium is rather soft; when hard the folds radiate out from the centre in a more or less even manner.

CULTURES FROM SCORCHED TREES.

Stems of the trees attacked by borers, from estates which were troubled with leaf fires, were taken to the Laboratory and the fungus isolated from them. Specimens from two estates were treated and typical non-zoned cultures were obtained starting from small pieces of the black lines.

CULTURES FROM CONIDIA AND ASCOSPORES.

From another estate which suffered similar damage owing to a leaf fire a rubber log was obtained carrying a large fructification twelve inches long and four inches broad on the stem. Over the greater portion of the surface the smooth conidial layer was present. After two days in the Laboratory the ascospores began to be extruded from the perithecia over about one square inch of the stroma. Cultures were obtained from the ascospores by setting a few of these in flask cultures. Non-zoned cultures resulted.

Cultures are difficult to start from conidia. Numerous foreign spores fall on the flat fructifications, and these develop more quickly in cultures than those of *Ustulina zonata,* with the result that the latter is crowded out. Cultures were successfully established from conidia by carefully rubbing away the upper layers of old spores with a sterile needle, using young spores from beneath to inoculate test-tubes of potato-mush agar. These cultures when transferred to flasks showed an interesting transition, indicating that the zoning of the cultures is variable, depending largely on external conditions. Pl. VI, figs. 15–17 show a series of photographs of flask cultures originating from the conidia. Figs. 15 A and 15 B show a culture zoned on both surfaces. Fig. 16 A shows the zoning on the upper surface, but the photograph of the under surface 16 B shows that the zoning does not extend through the substance of the culture as in a typically zoned one. Fig. 17 B shows the under surface of a non-zoned culture, exactly similar to the under-surface shown in Fig. 16 B while Fig. 17 A shows the typical under-surface of a zoned culture.

The action of the light on the zoning was tested by inoculating flask cultures with small pieces of the crust taken from a zoned one. These cultures were allowed to grow for a few days till the zoning became apparent in all of them. At this stage some of those showing two or three rings were placed in the dark, the other allowed to stand in diffuse light in the Laboratory. The latter developed into zoned cultures. In those placed in the dark the zoning stops immediately. The zoning of the fungus in pure culture is not constant, but can be varied by changing the conditions under which it is growing.

Fructifications were not obtained in pure culture till the end of 1916. It was then found that if sufficient water is placed in the culture tube to cover the cotton wool and partially immerse the wood block, the fungus immediately commences to produce growths resembling fructifications. The top end of the wood block must project slightly above the surface of the water and be kept comparatively dry in order to provide a suitable place for inoculation. The fungus quickly strikes away, and growing down the block through the water produces thin, black plate-like structures resembling the plate-like fructification found in nature. The fungus grows through the cotton wool and in one case produced the "Kretschmaria" form on the lower end of the wood block. Two or three weeks after the "Kretschmaria" form was noticed, small protuberances appeared on the upper end block which finally took on the "Xylarial" form; these were black stalked with a small greenish-grey head. The latter colour was due to the production of the typical conidial layer. Slants were started from these conidia, and typical cultures obtained. Thus the whole cycle of the life history has been obtained with the exception of the ascospore stage.

Fertile fructifications have not yet been obtained in agar cultures. Small rhizomorphic-like strands which attain a height of ¼″ above the surface of the culture are often found (Pl. VII, fig. 18). These strands resemble the individual components of the lichenoid form of the fungus. They grow about in the culture medium in a very irregular manner, and are doubtless comparable with the black lines running through the rotten wood of plants affected with *U. zonata.*

These experiments prove that *Ustulina zonata* is the fungus largely responsible for the death of trees attacked by borers. Attacks by boring beetles would not prove serious if other agencies were not concerned. The connection between the insects and this fungus, which is the cause of one of the most serious diseases on old rubber we shall have to contend with in Malaya, renders the question of the control of collar-rot a difficult one. It is obvious, however, that strict attention must be given to all trees, stumps or logs in which borers are working.

FUNGUS IN THE WOOD.

The progress of the fungus in the tissues is well shown by Fig. 19, which shows an artificial inoculation at the collar. The fungus advances from the point of inoculation into the wood and spreads more quickly in this than in the bark. The wood assumes a brown colour as the fungus advances, this discoloration extending fairly evenly in the vertical and lateral directions. Attention may be called to the apparent zoning shown by the discoloured tissues.

The brown wood is permeated with thin hyaline hyphae largely confined to the medullary rays and fibres of the wood. The vessels are comparatively little affected; only when the black lines cross the vertical path of the vessels are hyphae noticeable in them.

The fungus causes a drying of the affected tissues; the wood becomes crumbly and falls apart under the pressure of the fingers in advanced cases. The black lines of fungus tissue appear as the affected wood dries. These lines are formed by the aggregation and massing of hyaline hyphae; this aggregation always commences in the medullary rays (Pl. VII, fig. 20). Later, tracts of connecting cells between the rays become filled with similar tissue, and a continuous line is formed. Carbonaceous material is deposited in the cells after aggregation, and as time passes it is often difficult to detect their origin. The elements bordering the lines are crowded with hyaline hyphae.

The slow progress of the fungus in the root system is connected with its method of penetrating the tissues. The vessels are the routes along which quick travelling fungi, such as *Diplodia cacaoicola* (P. Henn) and *Corticium salmonicolor* (Zimm.) proceed, and the hyphae of these fungi are always specially noticeable in the vessels. *C. salmonicolor* is noteworthy in this respect, for as it passes along the vessels the living cells bordering them produce tyloses (2) in an attempt to stop the progress of the fungus. The vessels in wood attacked by *U. zonata* seldom show these ingrowths; Brooks (1) also calls attention to this absence of tyloses.

BLACK LINES IN ROTTING WOOD.

The tendency for fungi to produce black lines similar to those described for *U. zonata* is a noteworthy feature in the tropics. All rotting soft-wood logs on the plantations show these lines when the wood is cut. These lines are an important diagnostic feature to the planter, and more certain knowledge of the fungi forming lines in rotting soft wood on the plantations is desirable. A special investigation is under weigh, results of which are not yet to hand.

INOCULATION EXPERIMENTS.

The inoculations described by Brooks (1) indicate that the fungus will easily enter the collar of a rubber tree through wounds, but cannot enter a healthy unwounded tree. On very young unwounded seedlings, he obtained successful artificial inoculations, but similar trials on woody plants were unsuccessful.

Usually a fungus is limited in its infective capacity to either the aerial or underground portions of a plant, i.e. a fungus causing a root-rot will not attack the stems and branches of a particular host, and *vice versa*. *A priori* considerations lead to the conclusion that a wound parasite on roots might easily attack branches through wounds, but experimental evidence was desirable. The inoculation experiments to be described settle this question, and also bring evidence to support the result arrived at by culture experiments and field observations which proved that *U. zonata* is the organism causing the rotting of the tissues in rubber stems and branches attacked by borers.

Roots were inoculated with the fungus (*U, s*) isolated from the stem and branches, and branches were inoculated with the fungus (*U, r*) isolated from the roots.

Expt. 1. Eight seedlings were inoculated on 17. vi. 15. These plants were six months old, and had developed a woody stem at and for about eight inches above the collar. Four were inoculated with (*U, r*) four with (*U, s*). The inoculations were made by placing small pieces of rubber wood on which the fungus was growing in pure culture in slight cuts made with a sterile knife, either in the collar or woody parts of the stem. Control plants were kept; these were treated in the same way, but small pieces of newly sterilised wood were placed in the cuts. The results are placed in tabular form below.

Date examined	*U* (*r*) at collar		*U* (*r*) in in stem		*U* (*s*) at collar		*U* (*s*) in in stem	
No.	1*	2*	3*	4*	5*	6*	7*	8*
24. vii. 15	...	+	...	...	...	...	...	...
27. vii. 15	...	...	...	...	...	...	+	...
29. vii. 15	...	...	+	...	...	...	...	...
11. viii. 15	+	...	...	...	...	...	...	...
5. x. 15	...	...	...	+	+	...	...	...
6. x. 15	...	...	...	...	...	−	...	+

* Nos. 1, 2, 3 and 7 were dead on the date of examination. The death symptoms were typical, the leaves suddenly wilting. When the plants were cut open at the point of inoculation the progress of the fungus for one or two inches above and below this place was clear, and black lines were forming in the diseased tissues from the wounded places. No. 5 gave a similar result, but the plant was examined before the leaves wilted. Nos. 4 and 8 showed the fungus progressing in the tissues on the date of examination, while No. 6 completely recovered. Cuts made in control plants all healed quickly.

Expt. 2. In this experiment, similar inoculations were carried out on five year old, untapped trees growing in an area clear of all rotting timber. Eighteen trees were inoculated, nine with *U* (*r*), nine with *U* (*s*). Six each of *U* (*r*) and *U* (*s*) were made at the collar, the bark being lifted with a sterile knife, and a small piece of culture wood inserted. Six inoculations were made in the branches, three with *U* (*r*), three with *U* (*s*). These were made by cutting deeply into the cortex and inserting similar pieces of culture wood as those used in the collar inoculations. Inoculations made: 22. vi. 15, and examined: 1. ii. 16.

Tree No.	*U* (*r*) at collar	Tree No.	*U* (*r*) in branches	Tree No.	*U* (*s*) in branches	Tree No.	*U* (*s*) at collar	Remarks
1	+	7	+	10	+	13	+	Lost may be taken as unsuccessful
2	+	8	+	11	−	14	−	
3	+	9	+	12	+	15	+	
4	+	...	...	...	...	16	Lost	
5	−	...	...	...	...	17	+	
6	Lost	...	...	...	...	18	Lost	

The tabulated results of Experiment 2 show that twelve out of eighteen inoculations were successful. The branch inoculations were uniformly good, both with *U* (*r*) and *U* (*s*). Seven out of twelve root inoculations were successful. Considering the difficulties attached to root inoculations, this result is most conclusive.

The rapidity of the healing of the wounds in the control plants is noteworthy. In Experiment 1, observations were continued for some time comparing Nos. 4 and 8, in which cases the fungus penetrated slowly about the wounded part, and the control plants where sterilised slips of wood were placed in the cuts. Healthy callus healed the wounds in the controls in two months, while the wounds in Nos. 4 and 8 showed no signs of healing after three and four months. Compared with No. 6, which recovered completely, the cuts in the controls healed much more rapidly. The control plants in both experiments continued to flourish.

These inoculation experiments confirm the conclusions arrived at by field observations and cultural experiments. The capacity of *Ustulina zonata* to attack either the roots or aerial parts of rubber trees through wounds can no longer be doubted. The fungus makes very appreciable progress in the tissues in six months' time as is indicated by the photographs shown, Pl. VII, fig. 19 and Pl. VIII, fig. 21. The common occurrence of this fungus on the plantations renders it a matter of extreme import that vigorous measures should be undertaken to prevent its spread. The measures to be adopted will now be considered.

SOURCES AND MANNER OF INFECTION.

Petch (4) states that *Ustulina zonata* is the cause of the commonest root disease of Tea in Ceylon, and that its prevalence is due to the practice of growing *Grevillea* among tea and cutting it out later for firewood, or when it has grown too big. The same applies when *Albizzia moluccana* is planted through tea, and afterwards felled. The *Grevillea* and *Albizzia* stumps left in the ground are rotted away owing to the action of fungi, and *U. zonata* is the commonest one growing in them. In the same way, this fungus appears to be one of the chief agents causing the rotting of rubber stumps and logs left in the plantations after thinning-out.

On the tea plantations, the fungus enters the *Grevillea* and *Albizzia* stumps and grows down them into the lateral roots. The roots of the tea bushes in contact with these infected laterals are quickly attacked. The same method of spread operates in the rubber plantations after the thinning-out period if the stumps of the cut trees are left in the ground. Lateral roots of infected trees have been traced to old rubber stumps left after thinning, on which the fructifications of the fungus were developing. Further, on the badly affected plantations noted up to date, the stumps of the rubber trees were not removed after thinning-out.

There is, in Malaya, a wide-spread dispersal of the fungus through the plantations by means of the spores after the thinning-out period. The fungus enters permanent trees attacked by boring beetles and quickly kills them, and the stumps and felled logs form excellent material in which the beetles and fungus may work together. But the fungus alone can enter and grow through any soft-wood timber without the aid of the insects.

All trees attacked by boring beetles should be immediately cut out and destroyed, as they represent one of the worst sources of infection. Strict attention should be given to trees scorched by fire, and if borers attempt to enter, a coating of tar and crude oil (80 per cent.–20 per cent.) should be applied over the scorched surfaces. In the case of scorched trees resulting from leaf fires, the burnt areas are usually situated near ground level, and can be easily treated with the tar mixture. A second coating should quickly follow the first. Scorching of higher branches resulting from burning of piles of timber is not so easily treated, but as far as observation goes, these branches are not often attacked by the insects; in any case they can be cut away from the main stem quite easily.

The cases of leaf fires noted this year—1916—support the observations made in 1915 and given above. One interesting case was noted: an estate was visited four days after the fire and borers were already at work on half a dozen trees not badly scorched; latex was exuding freely from the boreholes.

At the time of thinning-out a tremendous increase of suitable food material for the fungus becomes available. Practically all stumps and felled logs of rubber if left lying about the plantation for any length of time show signs of *Ustulina zonata*. The fructifications develop on the surface of these logs and stumps, and for a short period corresponding to the weekly one observed in the Laboratory, a copious supply of spores (conidia) is produced and blown about the plantation by the wind. Later, the ascospores ripen, and these are distributed amongst the trees by various agencies.

The spores come to rest in wounds in the collar and lateral roots of the permanent trees and under suitable conditions germinate. The fungus develops slowly, and several years later when the trees are passing the ten years' limit, some begin to show a thin crown of leaves. If the collar is now cut open, the characteristic dry-rot will be found.

The fungus is also found on rotting jungle timber and on old jungle stumps left in the plantations after burning-off. It is not so common in the early years as it is during or after the thinning-out period, though many cases have been found recently of roots of four year old trees permeated and killed by this fungus. The jungle stumps and timber represent one of the sources from which the fungus commences, for fructifications have been obtained from old jungle stumps (Pl. III, fig. 2) and characteristic symptoms have been observed in lateral roots of jungle stumps exposed in areas treated for *Fomes lignosus.*

It is probable that healthy jungle trees are attacked by this fungus, and spores may be blown from the jungle into the plantations. It is impossible to take the measures to prevent the spread of the fungus from this source. On a clean estate, there is little danger to be anticipated, and in the general scheme of treatment it may be considered negligible.

TREATMENT.

This consideration of the sources and manner of infection indicates that present day plantations may be divided into three groups. The treatment accorded to each group varies with age. The groups are as follows:

(*A*). *Young plantations not thinned out.*

(*B*) *Plantations thinning-out with trees not ten years old.*

(*C*) *Plantations with trees over ten years of age.*

(*a*) Control measures against the collar-rot caused by *Ustulina zonata* may be initiated by enforcing strict sanitation methods from the time of planting up. The clearing of the ground of rotting timber and the treatment of jungle stumps is the first and immediate measure to be undertaken. This will largely prevent trouble from *White ants* and *Fomes lignosus,* as well as minimising that likely to ensue from attacks of *Ustulina zonata.* Special attention should be paid to the eradication of the lateral roots of jungle stumps to prevent contact infection from both *Fomes lignosus* and *Ustulina zonata.* This can be secured best by following up the laterals from the stumps to a depth of two feet below the surface. At this point they should be cut through and separated from the parent stump. Clearing timber and eradicating stumps or lateral roots is costly, and the difficulty of the undertaking fully appreciated. Though many of the larger stumps will have to be left standing, yet it is possible to clear any estate to such an extent that trouble from root diseases may be reduced to a negligible quantity.

On estates badly affected with *Fomes semitostus,* the elimination of stumps and timber, as far as is practicable, has been fully recompensed. General treatment on these lines could not be advised previously, for large numbers of estates are free from "Fomes" troubles, but few will escape attacks by *Ustulina zonata.* This fungus appears likely to cause damage on most old properties.

(*b*) *Plantations thinning-out with trees not yet ten years old.*

Estates about to thin out from which no jungle stumps have been removed or timber cleared, should attempt to follow the advice given under (*a*). On all estates the method of thinning-out should follow the same lines as treatment advised for clearing land at the beginning. One tree should be cut, and the stump, lateral roots and logs removed and destroyed immediately. A sharp watch should be kept over the thinned area for signs of borer attacks on standing trees and those attacked should be cut out and destroyed quickly. This treatment prevents the multiplication of boring beetles by destroying their breeding grounds.

PERIOD AFTER TREES ARE TEN YEARS OLD.

On most old plantations in Malaya, this disease will be found to be responsible for the death of numerous trees. In a previous publication (10) the writer stated that it might be possible to treat old trees attacked at the collar by cutting out the diseased tissues and running a pillar of concrete up the middle. Since then, this method has been tried, but from the planters' point of view is unsatisfactory because of the expense. Therefore, if diseased trees are found in an advanced state of decay, they should be cut out immediately, care being taken to remove all diseased laterals to prevent contact infection. The greatest damage on old plantations arises from infection of roots of healthy trees by contact with diseased laterals of neighbouring trees; the recognition of this fact must not lead to a minimisation of the dangers of spore infection.

Fructifications are common on the surface of the diseased tissues at the collar. They develop quickly, so a constant watch should be kept on attacked trees, if left standing. Two examinations a week would be advisable, and immediately fructifications are observed, a tin of kerosene oil should be obtained and the fruit-body gathered and immersed in the oil. This will help to prevent the spread of the fungus about the plantation by means of wind-borne spores. Wounded lateral roots on trees over six years old showing above the surface of the soil are convenient places of entry for the fungus. Such roots showing black lines below the wounds should be cut off if they can be spared.

Many managers see difficulties in the amount of burning which is required. Burning, however, is carried out successfully all the year round on many estates in the treatment of "Pink Disease," with little damage to the permanent trees.

FUTURE POLICY AND CONCLUSION.

It is an accepted fact that pests and diseases are a constant menace to all plantation industries. The potential dangers to the Rubber Plantations in Malaya are becoming more manifest each year, and the menace is doubly dangerous because of the comparative immunity of the plantations up to date, which has lulled responsible persons into a false sense of security. Many significant facts have been brought to light during the last two years. A few cases of serious attacks of root disease in rubber plantations might be quoted:

(*a*) On one estate, a block of 6–7 acres of sixteen year old rubber was examined—sixty trees to the acre. A casual inspection revealed 120 trees attacked by *U. zonata*. More have since been found.

(*b*) The Government estate behind the offices of the Department of Agriculture at Kuala Lumpur carries about seven acres of fifteen years old trees. A fair number of cases of *U. zonata* were known, but only one small group of six trees was known to be affected with "wet root-rot[1]." To obtain specimens and observe the disease below ground, this group, together with the neighbouring trees, was opened up. It was obvious from the commencement that the subterranean spread was much greater than at first anticipated. Two hundred and twelve trees were opened up, and forty per cent. showed diseased roots (i.e. wet root-rot). The matter was so serious that at the request of the Advisory Committee to the Department of Agriculture, the whole of the seven acres of old rubber had their roots exposed. Over the whole area, in which 700 trees were examined, twenty per cent. showed diseased roots.

(*c*) A third illuminating case was noted some months ago. A wind storm, locally known as "Sumatra," swept over a portion of one estate, and a large number of seventeen year old trees were blown over. Of these prostrate trees, only three showed healthy roots; these were without tap roots. A few of the fallen trees had been treated previously for *U. zonata*, but by far the great majority which were not suspected to be suffering from root disease, had *U. zonata* attacking the roots. A few cases of branch infections with *U. zonata* and a few roots with wet root-rot, were also found. When the place is cleared, huge gaps must be left in the wind swept area. The manager is quite certain that any other portion of the old rubber subjected to a similar storm would show a larger number of unsuspected cases of root disease. This, and the case quoted immediately above, shows the insidious spread of these root fungi on old rubber, and it is impossible to urge too strongly the necessity for immediate and strenuous measures to keep them under control.

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[1] Belgrave, W. N. C. "A Root disease of Plantation Rubber in Malaya." *Agr. Bull. Fed. Malay States*, Vol. IV. No. 11. Aug. 1916.

A further complication arises: during the last six months, serious outbreaks of different manifestations of so-called Bark Canker have been found in widely separated districts in Malaya. The important point in combating diseases of renewing bark is that the trees should be assured proper ventilation. The more light and air penetrating to the trees, the less chance of epidemics of Bark Canker. If Bark Canker becomes general in Malaya, thinning-out will have to be undertaken to the irreducible minimum number of trees per acre commensurate with profitable working. When estates are forced to this position, the menace of a bad attack of root disease is obvious.

A critical period approaches for the plantation rubber industry in Malaya. No immediate danger promises though the menace of disease becomes more prominent every year. Fungus diseases will, in the long run, provide the limiting factor, preventing the expansion and hindering the progress of the industry. The logical conclusion drawn from facts as they present themselves is that if preventive measures are not immediately adopted, fungus diseases may prove the ultimate ruin of an industry, which with careful foresight and administration, should smother all competitors for decades.

The future policy to be adopted in Malayan rubber plantations must be one of two: either

(*a*) An attempt to keep the present plantations healthy as long as possible, or

(*b*) A re-planting scheme at an age between 20–30 years.

The profits gained by a rubber plantation depend upon the average yield of dry rubber per acre per annum. There is little evidence regarding average yields to be obtained from a consideration of present day estates approaching the age of twenty years, and that available is contradictory. Some old areas yield remarkably well, while others give comparatively poor yields. There are reliable records (6) of a thirty-seven year old tree giving 392 lbs. 7 ozs. of total rubber in five years, a yearly average of 78 lbs. 8 ozs. There are also reports of old trees in Malaya giving enormous yields, but these cannot be claimed to be authentic. There appears no reason why plantation trees in Malaya should not approach the above standard, and if such yields are possible the policy of rendering the present plantations as permanent as possible should be adopted. At the same time it will be advisable to move cautiously, for observations on one estate, run on up-to-date lines, lead to the conclusion that the yields on the present plantations with 50–60 trees per acre, begin to decrease after the trees are twenty years old. It must be remembered, however, that these old areas passed through the "boom" period when the only question considered was that of a maximum yield without any regard for the health of the tree, and it is not possible to hazard what effect such treatment would have. Further, root diseases on this area are giving a great amount of trouble, causing continual losses. The question of the permanence of the old trees is closely linked with the possibility of root diseases causing the death of large numbers. These diseases in rubber plantations can be reduced to a negligible quantity if the land is cleared before planting up is commenced, and though the result of clearing plantations now in bearing is more problematical, the estates undertaking this will be fully recompensed by freedom from fungus disease.

If the fungi causing root-rots on old trees become active so as to endanger the plantations at thirty years, a fresh planting scheme must be considered. There are two alternatives:

(*a*) *Re-supplying old areas.*

To re-supply successfully the stumps, lateral roots and logs of all the old trees would have to be burnt off and the ground allowed to lie fallow for at least twelve months, or a subsidiary crop might be grown on the land during this period. If clearing was not thoroughly undertaken, the root-rot fungi would find conditions more favourable for perpetuation and spread than in the previous years, and an exaggerated recurrence of thinning-out conditions would result. Instead of the root-rots becoming serious at ten years old, they might be expected to prove serious much earlier, and numerous young trees would be killed by these fungi.

(*b*) *Planting new areas.*

New contiguous areas opened up near old areas containing diseased trees are doomed to failure unless the latter are cleared. Presumably, the old areas would be gradually abandoned, and in the interests of economy, the rotting trees would be allowed to remain. Such areas would prove to be centres of infection, and it is extremely probable that the new areas would be quickly infected. The parasitism of these fungi may increase in vigour with time, and as observations show, young plants are easily attacked under suitable conditions.

FUTURE RESEARCH.

The evidence favours an endeavour to keep the present plantations active until age prevents the old trees from yielding profitably. Many magnificent looking trees are poor yielders; this fact together with possible losses from disease has been the great stay for the argument that more trees should be kept to the acre than are absolutely necessary. This is an obvious but clumsy way of insuring a profitable yield, but until a better method is suggested it must remain in force. An optimum number of trees per acre is the ideal—this postulates average yielding trees and few or no losses from disease after the ten years limit is reached. Rubber estates developed with a due regard to hygienic principles need not fear losses from disease as far as present knowledge goes; this statement obtains more support the further investigations are carried.

Fears for the future should not lead rubber people to favour the retention of trees in excess of the optimum, but should stimulate them to insist upon responsible persons finding the ways and means of surmounting the difficulties by approaching cognate problems from different perspectives. The solution lies in the adoption of an intensive scheme of scientific research.

Two lines call for immediate attention: (*a*) physiological investigation to enquire into the rôle played by latex in the metabolism of the tree; (*b*) seed selection investigations with a view to improving yields of latex and at the same time obtaining trees more resistant to fungus attacks. The inception of these investigations would mark a new departure in tropical research. Up-to-date, practical investigations have been all that were asked for; the problems have been so many and the workers so few that immediate matters have had to be hurriedly dealt with, and little attention has been paid to the future. The position is worse because of the lack of correlation in scientific investigations and the difficulty investigators find in meeting and discussing cognate problems from the experience gained in different countries. Rubber research needs centralisation and reorganisation, which would enable immediate practical matters to be grappled with, and would also institute pure scientific investigations with a view to rendering the industry a permanent cornerstone in the edifice of National Industry. With proper foresight and efficient administration, the rubber industry of the Middle East should remain largely under British control, and should fear no competitors. On the other hand, if the present methods continue, the result may be disastrous. The present time is ripe for a departure from archaic ideas, and if all interested parties can be brought together to reasonably discuss the situation, the outcome is assured.

I am indebted to Mr F. de la Mare Norris, Asst. Ag. Inspector, F. M. S., for the drawing of Fig. 20 and to E. W. King, Esq., Visiting Agent to the Kuala Lumpur Rubber Co., for the photograph included as Fig. 2.

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EXPLANATION OF PLATES.

PLATE III.

Fig. 1. Typical specimen of dry collar-rot on ten year old tree caused by *U. zonata.* ($\frac{1}{6}$ nat. size.)

Fig. 2. Flat Plate Fructifications of *U. zonata* on old jungle stump left in Plantation. (Photograph by E. W. King, Esq.)

Fig. 3. T.S. of Spec. (*A*) (see text) attacked by *U. zonata* and shot-hole borer. ($\frac{1}{2}$ nat. size.)

Fig. 4. L.S. of same showing bore-holes and black lines. ($\frac{1}{2}$ nat. size.)

PLATE IV.

Fig. 5. Photograph of scraped tree taken four days after scraping—showing latex exuding from bore-holes. ($\frac{1}{4}$ nat. size.)

Fig. 6. Same tree with bark removed exposing outer surface of wood—note black lines, etc.

Fig. 7. Lateral root carrying typical fructification of *U. zonata.* Note white patches of mycelium in bark; the black lines and zoning on the plates. ($\frac{1}{2}$ nat. size.)

Fig. 8. Hollow White-ant tree with *U. zonata.* The two black lines indicate the limits of the wood attacked by the fungus. ($\frac{1}{5}$ nat. size.)

PLATE V.

Fig. 9. Showing typical flat, zoned fructification. (½ nat. size.)

Fig. 10. Common variation—consisting of stalked individuals aggregated to form a compact mass. At the edges a lichenoid form can be seen, while old plate fructifications are present below but cannot be brought up in the photograph. (⅓ nat. size.)

Fig. 11. Isolated individual stalked (Xylaria) form—darker area at top indicates the spore bearing part. (Nat. size.)

Fig. 12. Microphotograph of longitudinal section of Fig. 11. The layer above the black line at the top is the spore bearing (conidial) layer.

PLATE VI.

Fig. 13. Another specimen of aggregated stalked form passing into lichenoid type at edges. (½ nat. size.)

Fig. 14. Lichenoid form of *U. zonata* in young condition. (Nat. size.)

Fig. 15A. Upper zoned surface of culture started from conidia.

Fig. 15B. Under surface of 15A—zoning extends through substance of culture.

Fig. 16A. Upper surface showing false zoning of culture started from same source as 15A and 15B.

Fig. 16B. Under non-zoned surface of 16A.

Fig. 17A. Typical zoned culture from collar-rot tree (under surface).

Fig. 17B. Showing typical under-surface of non-zoned culture started from same source as 15A and 16A.

PLATE VII.

Fig. 18. Petri dish zoned culture showing attempt to produce lichenoid form.

Fig. 19. Photograph of section of tree artificially inoculated at the collar. Indicates progress made by fungus in seven months. (¼ nat. size.)

Fig. 20. T.S. of wood of *H. Brasiliensis* attacked by *U. zonata*. Black lines commencing to form in medullary rays (*m*).

PLATE VIII.

Fig. 21. L.S. of scraped tree, see Figs. 5 and 6, indicates progress of fungus in stem in seven months time. (¼ nat. size.)

Fig. 22. Sections of lateral roots showing *U. zonata* travelling in the middle. External tissues apparently healthy. (¼ nat. size.)

Fig. 23. Blocks of rubber wood on which cultures of *U. zonata* have been grown. Split open to show black lines in middle. (Nat. size.)

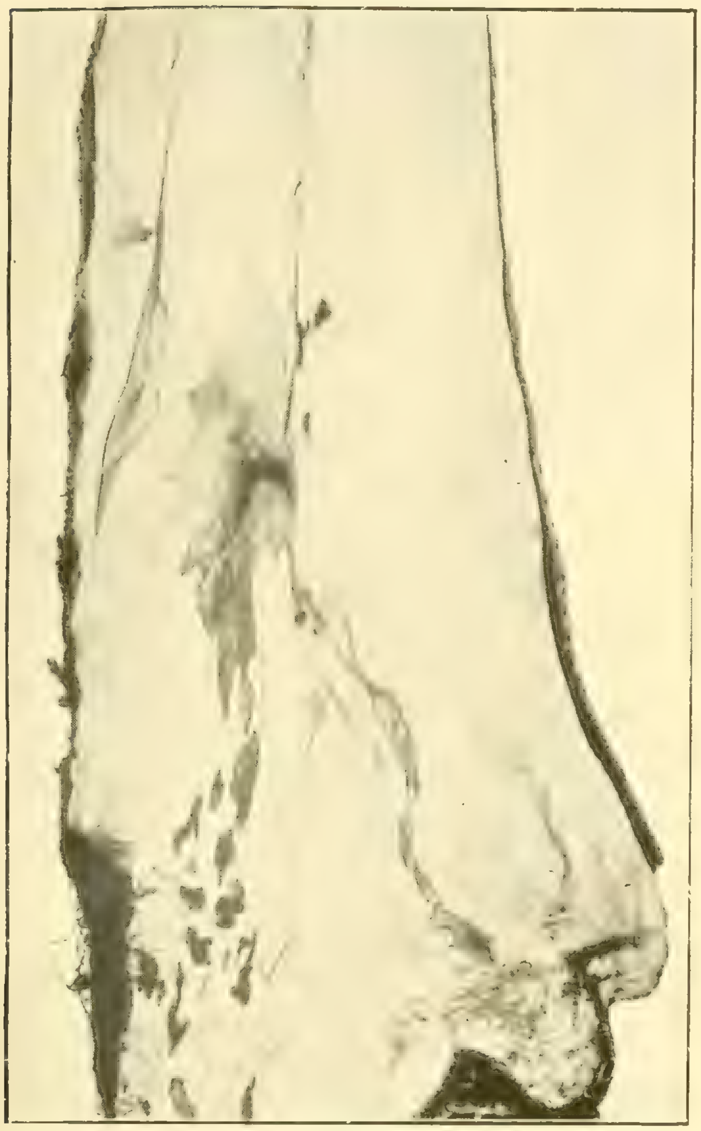


Fig. 1

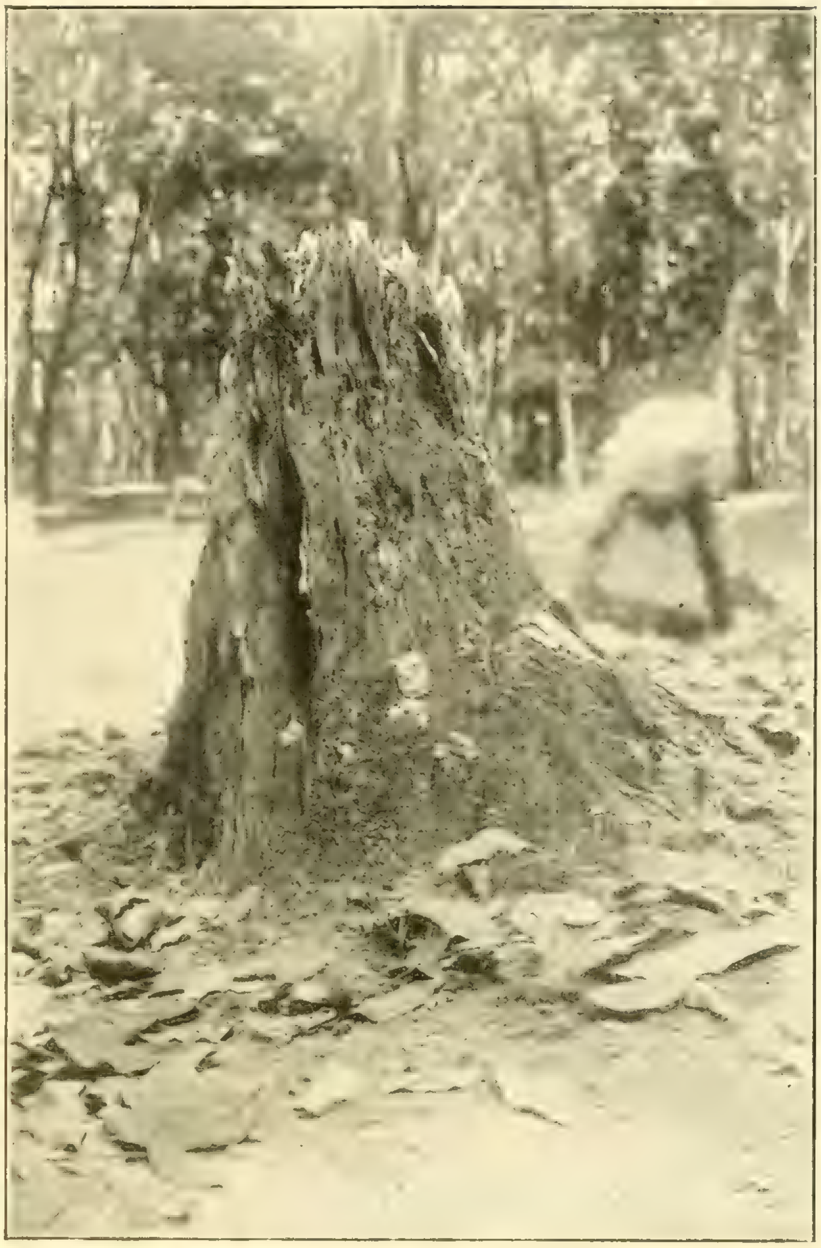


Fig. 2

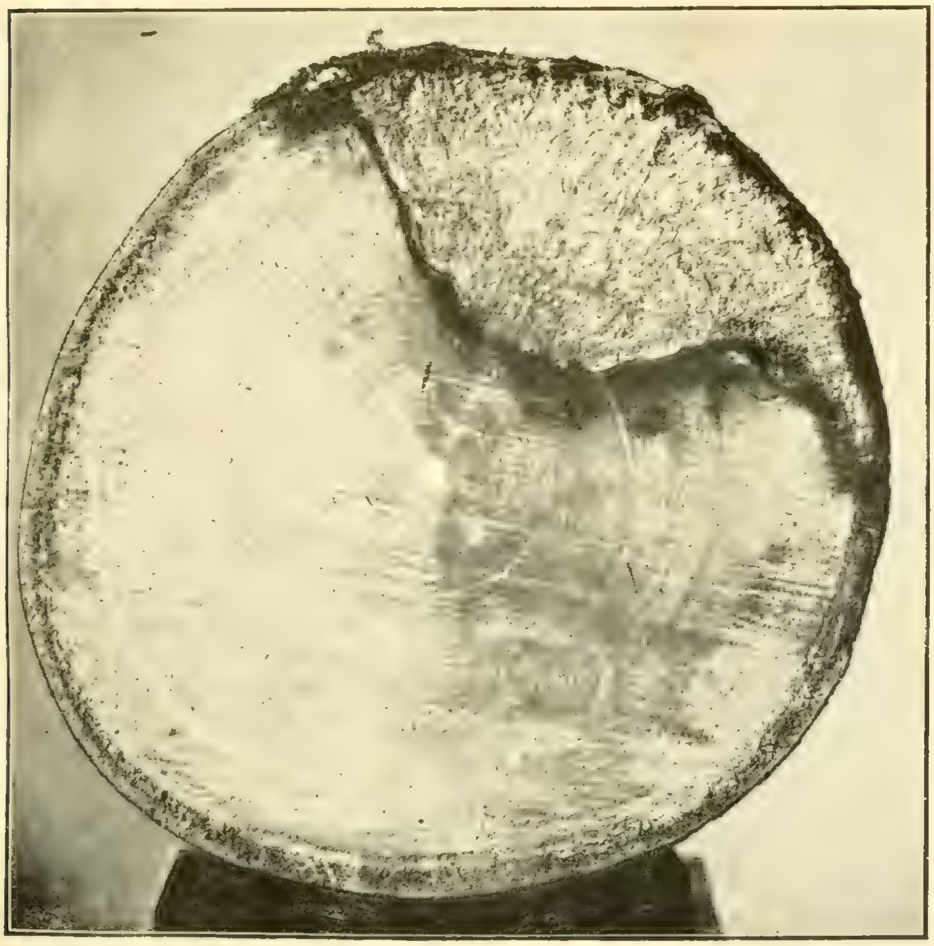
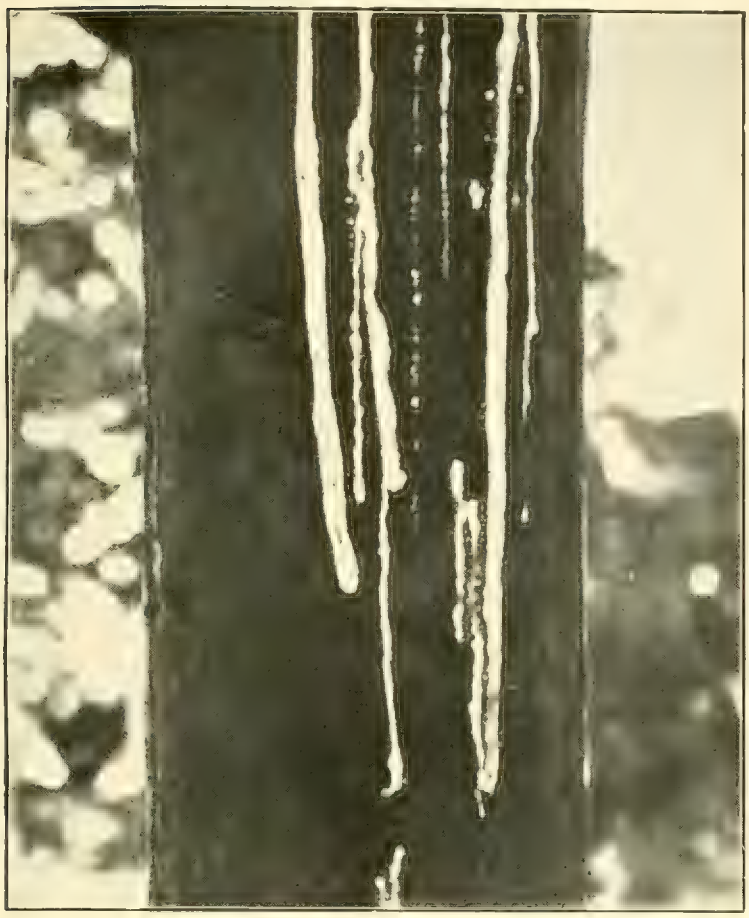


Fig. 3

Fig. 4



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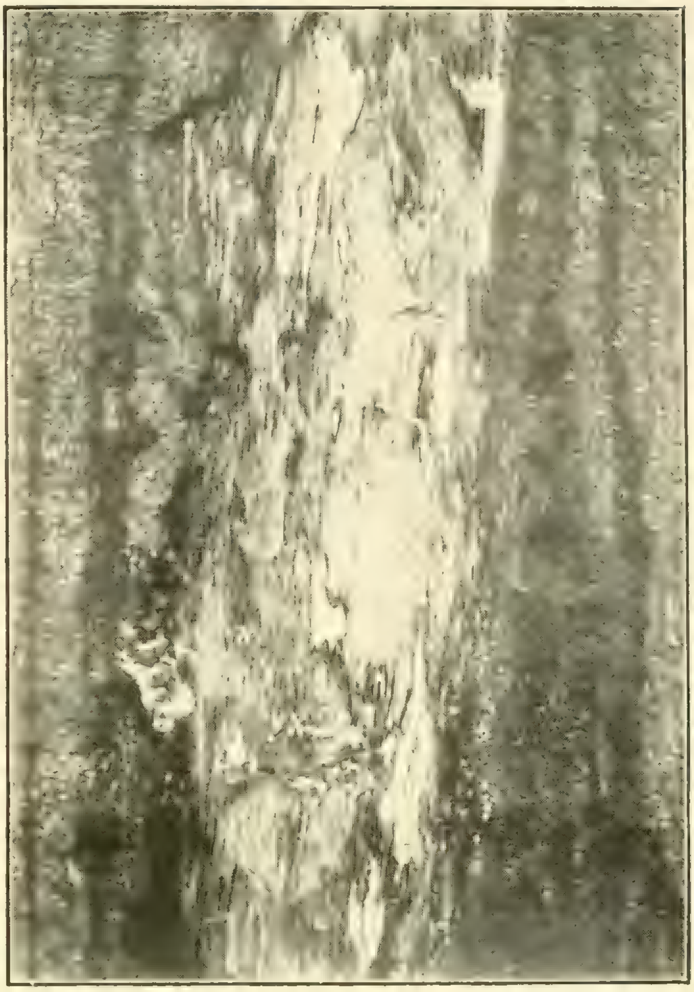

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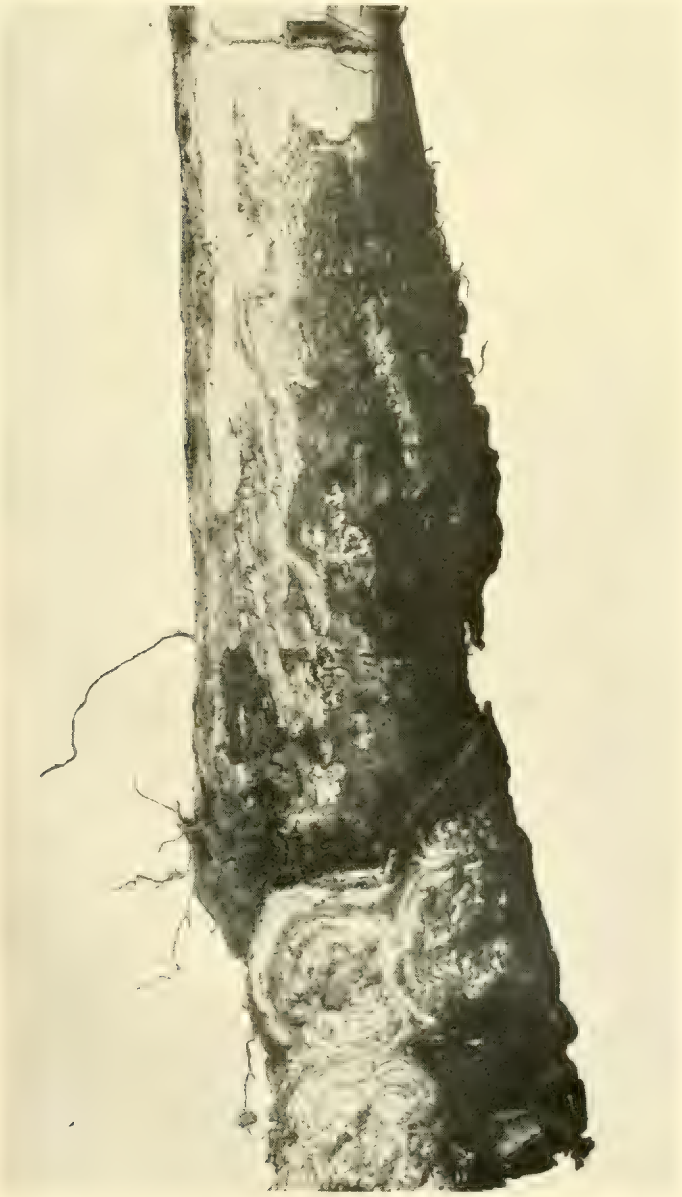

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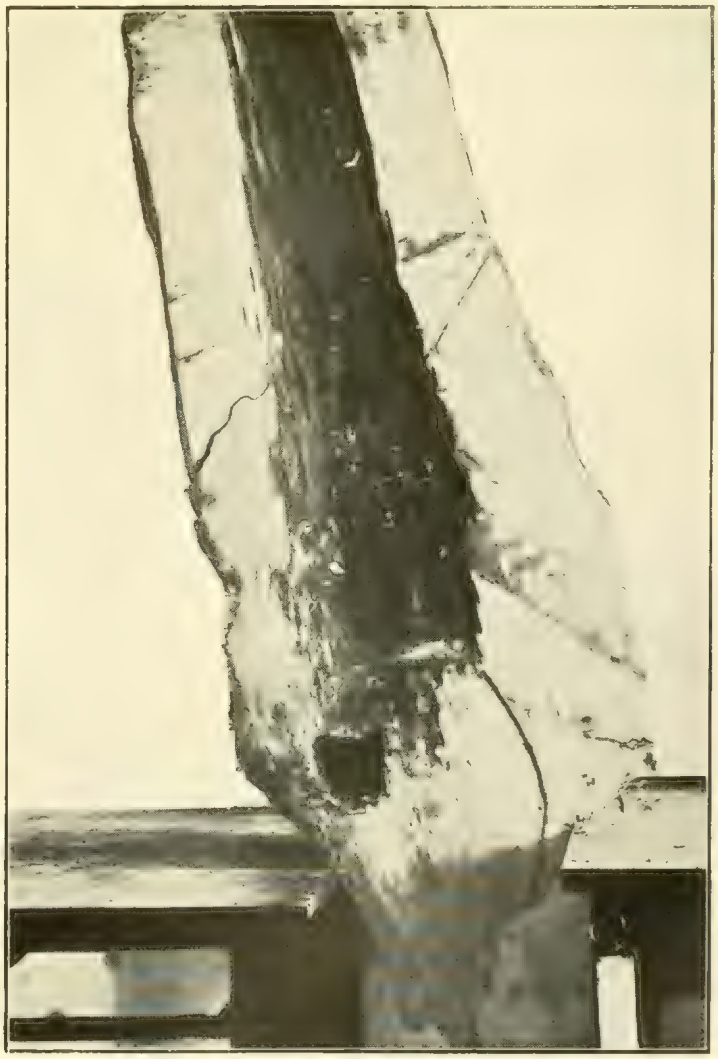


Fig. 8

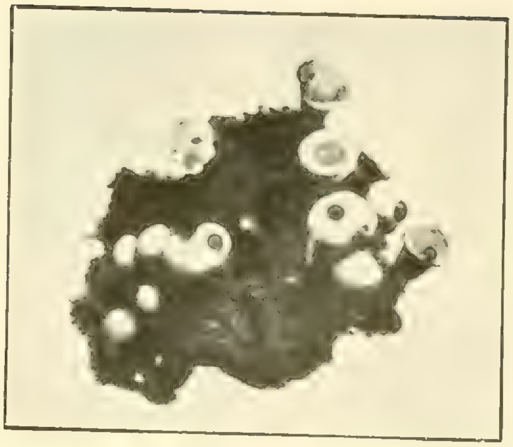


Fig. 11

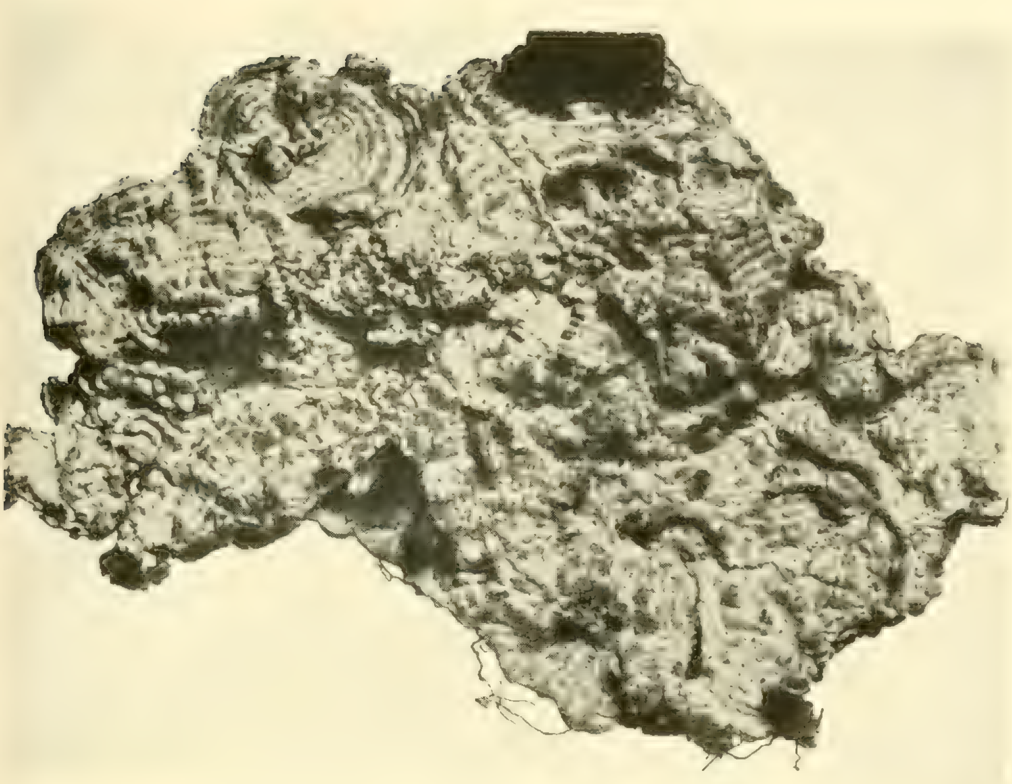
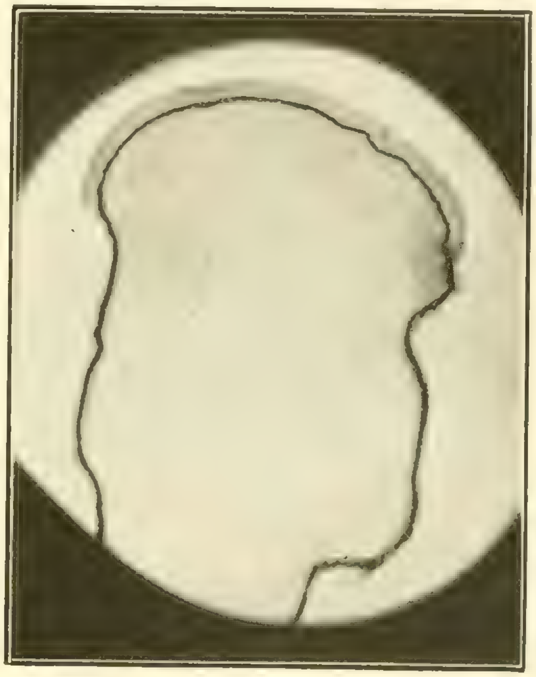


Fig. 9



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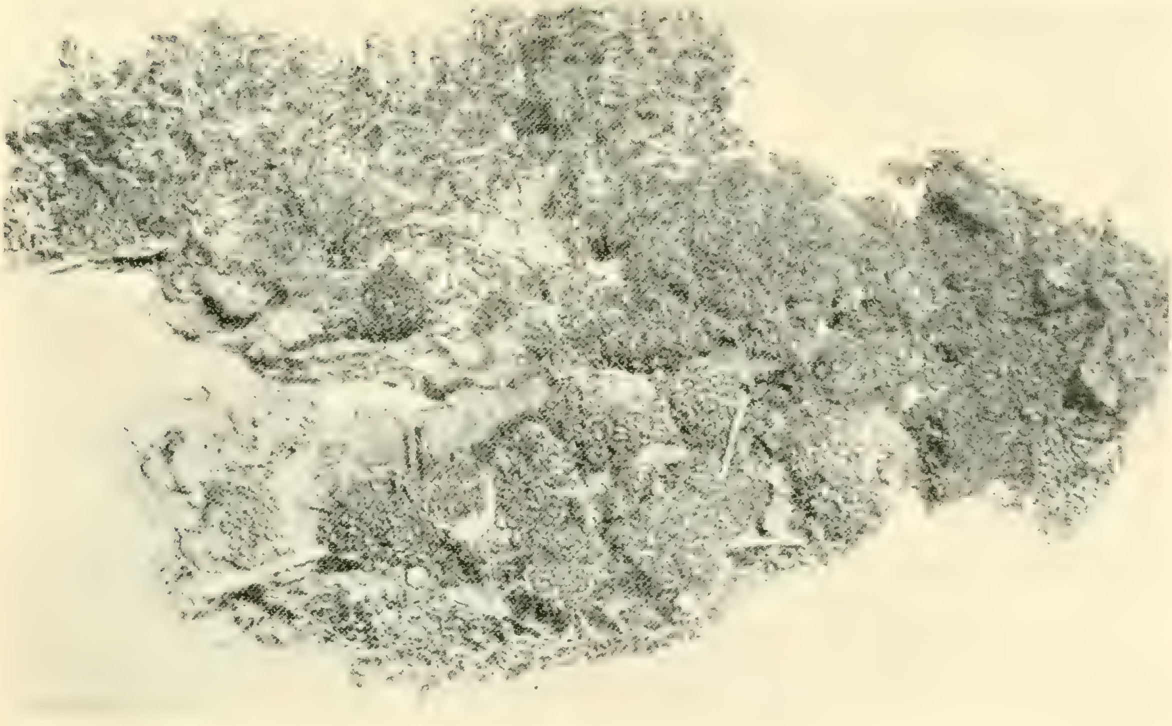
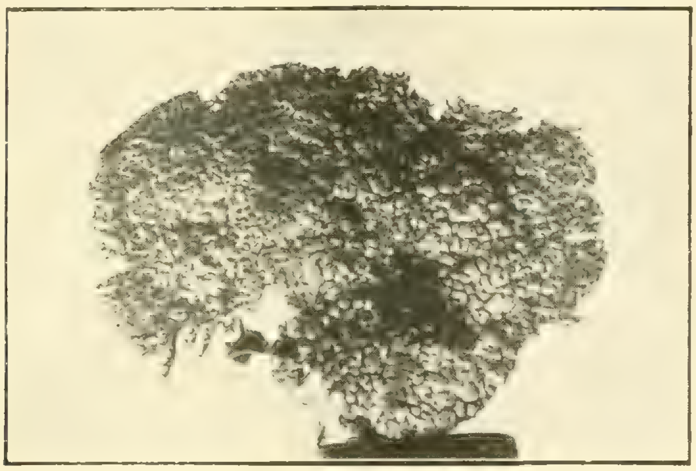


Fig. 10



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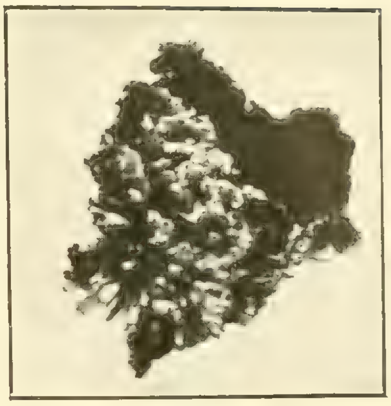

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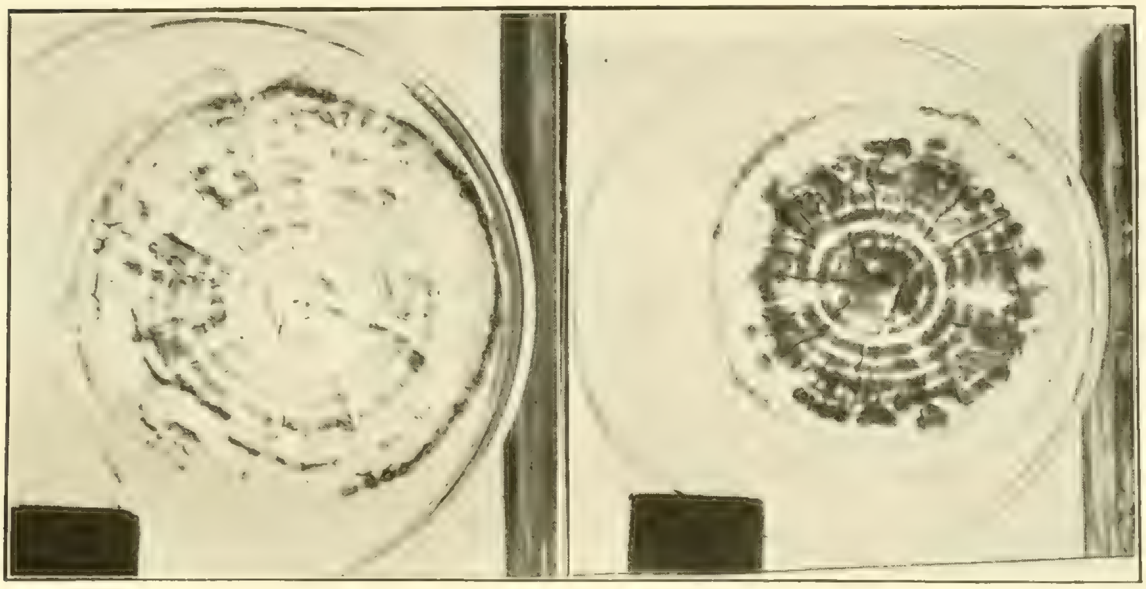
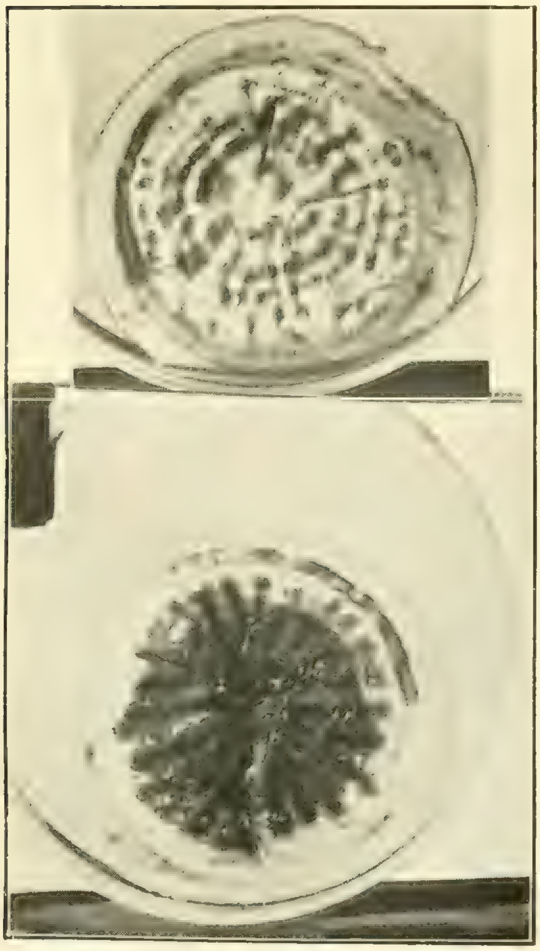


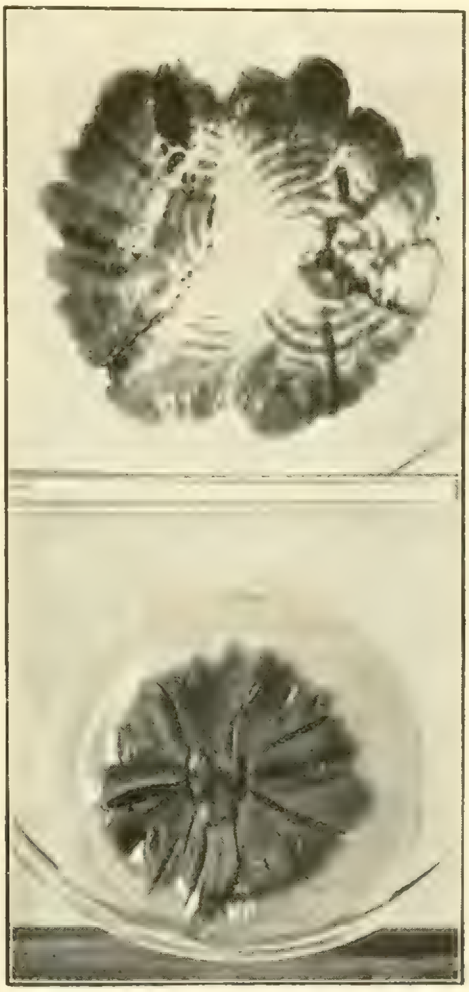
(A) Fig. 15. (B)



(A)

(B)

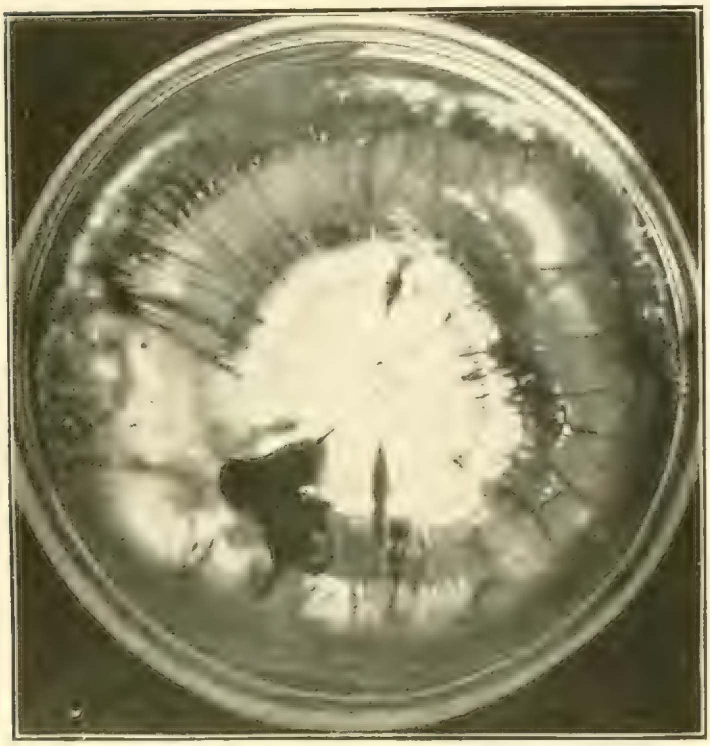
Fig. 16



(A)

(B)

Fig. 17



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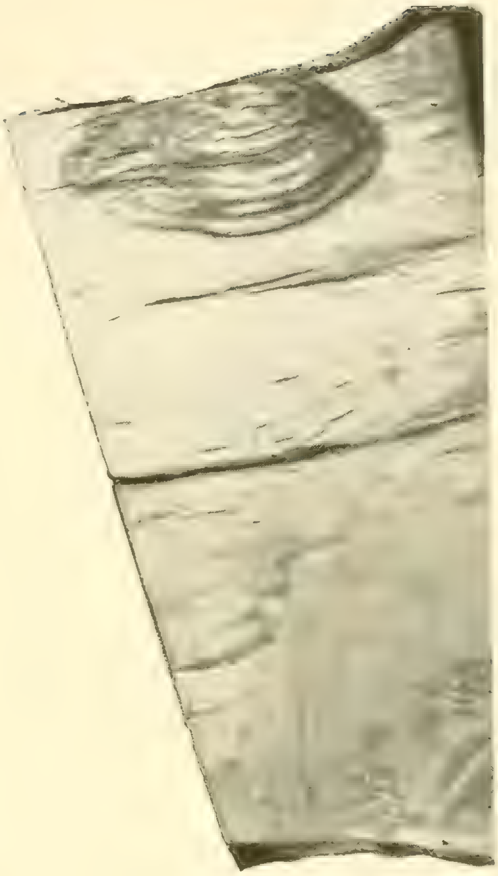

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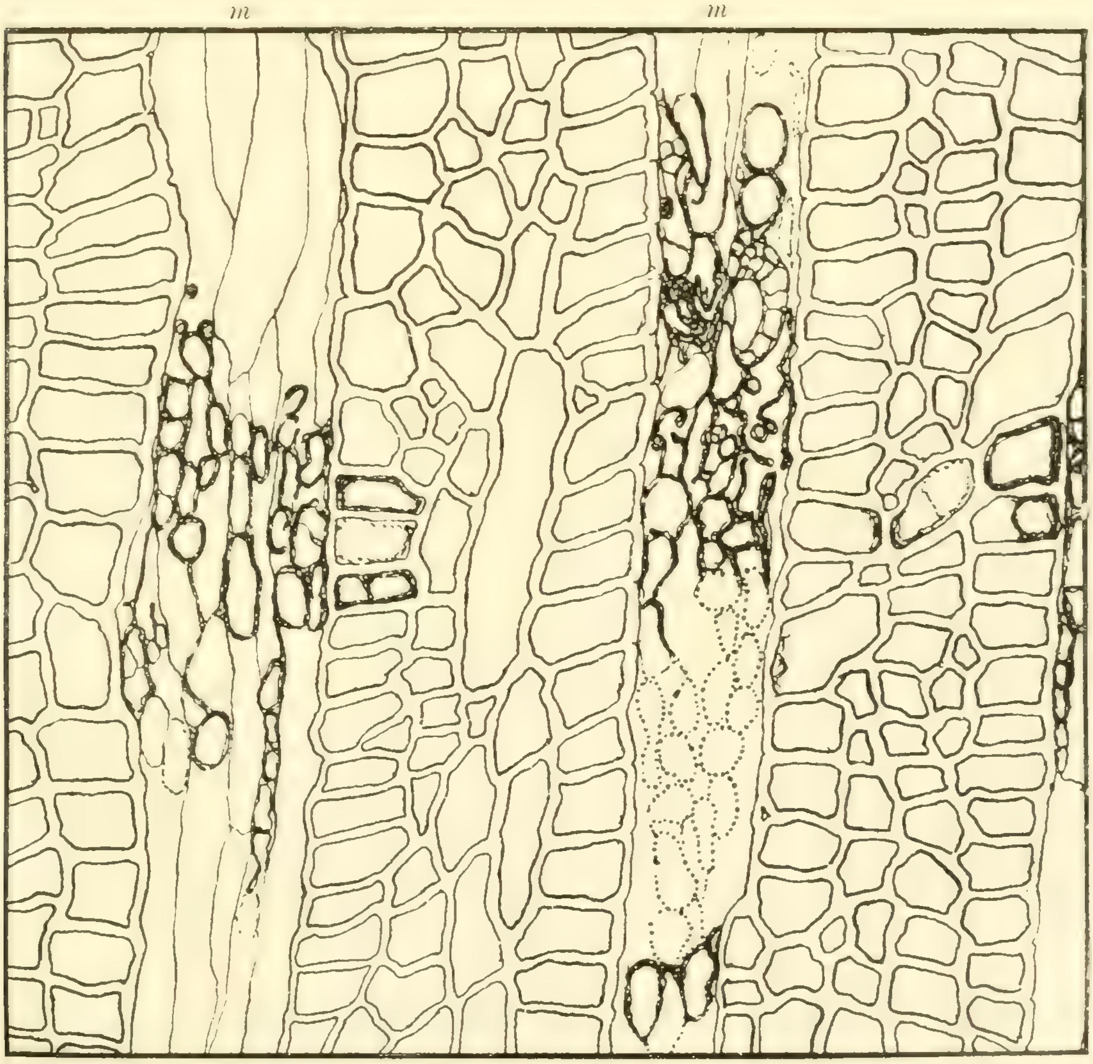

Fig. 20

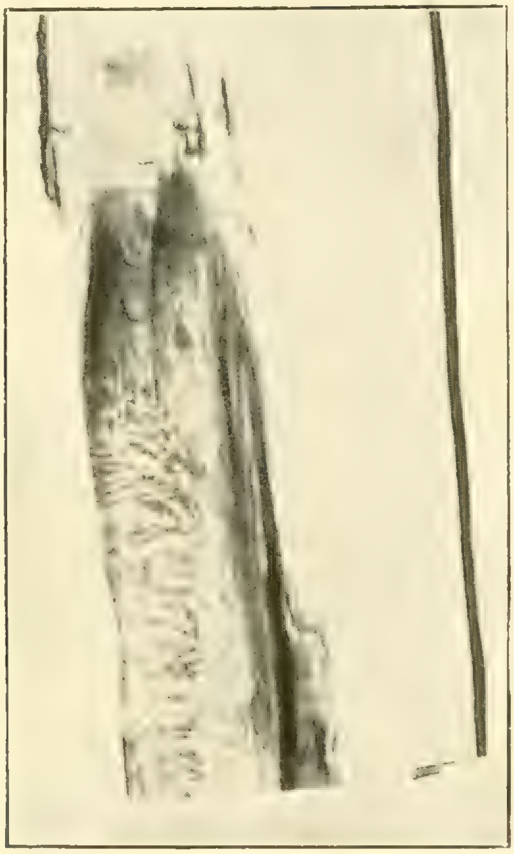

Fig. 21

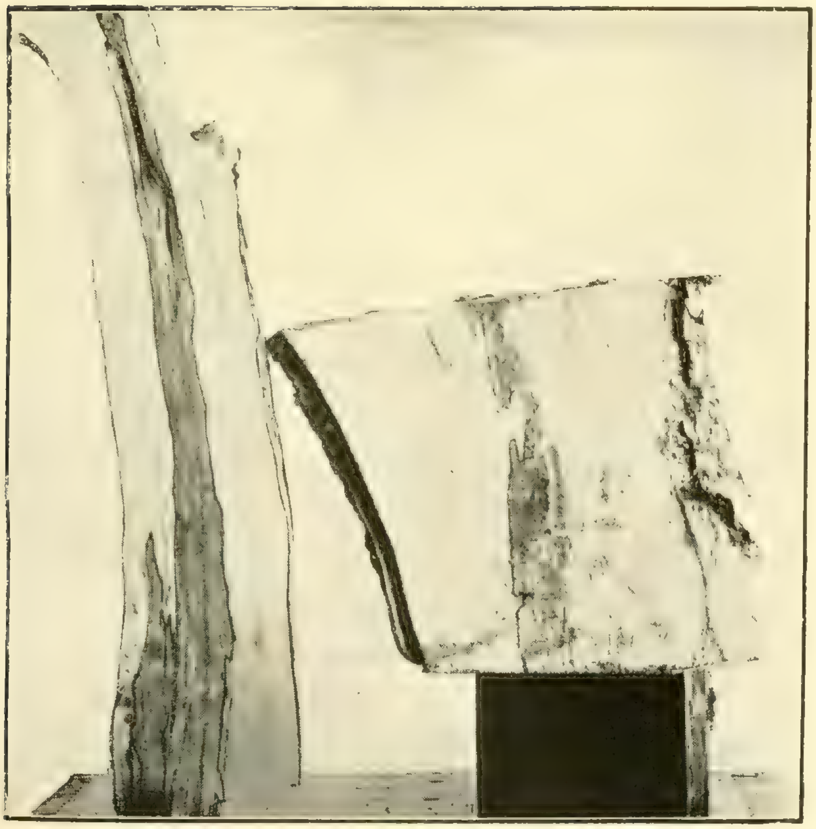

Fig. 22

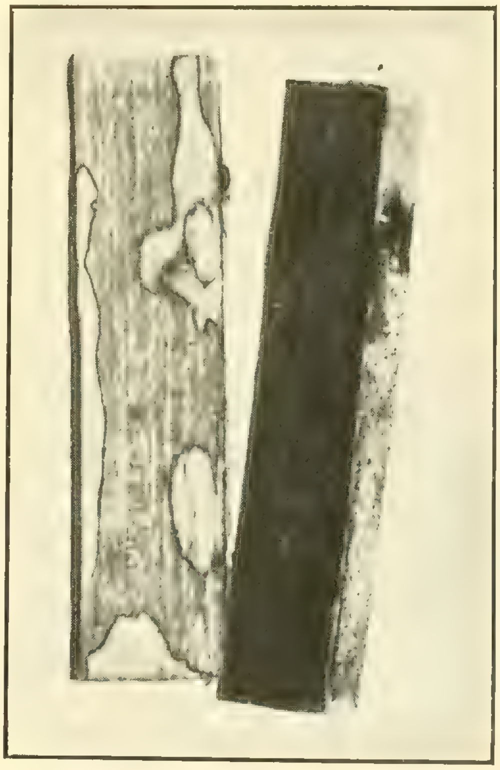

Fig. 23

A STUDY OF THE CAPSID BUGS FOUND ON APPLE TREES.

By F. R. PETHERBRIDGE and M. A. HUSAIN[1].

School of Agriculture, Cambridge.

(With Plates IX—XI.)

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1. INTRODUCTION

The damage done to apples by bugs of the family Capsidae has now become a very serious trouble to fruit growers in this country and a detailed knowledge of those found on apple trees is therefore of immediate importance. This work was undertaken at the suggestion of Fryer who has, during the past few years, made observations on these insects (11, 12, 12*a*).

---

[1] Mr Husain wishes to thank the Government Grant Committee of the Royal Society for the grant given to him to carry out this work.

The problem has been studied mainly from an economic standpoint, our main object being to find out the amount of damage caused by each species, to study their life-histories and the nature and cause of the injuries done to the leaves, shoot and fruit by the various stages.

Problems of great biological interest and possibly of economic importance have arisen during the course of this work which we have been unable to investigate owing to pressure of time. One season is a very short time to study all the aspects of such a problem as this, and we hope if circumstances permit to continue this work next season. Our justification for the publication of this rather incomplete paper is in the hope that the observations contained in it may be of immediate use in helping to control this serious pest, and also that under such abnormal conditions as exist at the present time, the authors may be unable to continue this work, in which case the observations made may be of some help to future investigators.

A large number of the Capsidae live on the juices of plants which they suck by means of their long rostra, and it is probably as a consequence of this that so many of them have been recorded, some rightly and others wrongly, as plant pests. In America the following have been recorded as damaging fruit trees:

Heterocordylus malinus Reut.
Lygidea mendax Reut.
Lygus pratensis Fab.
Neurocolpus nubilus Say.
Paracalocoris colon Say.

Fryer points out that of these only *Lygus pratensis* is present in this country.

In England the following among others have been recorded as damaging apple trees:

Atractotomus mali Mey.
Lygus pratensis Fab.
Orthotylus marginalis Reut.
Plesiocoris rugicollis Fall.
Psallus ambiguus Fall.

Lygus pratensis is recorded as producing dimples on apples, whereas the others are recorded as damaging the leaves, shoots and fruit.

As Fryer has pointed out (11) there is a great deal of confusion as regards the real pest and the status of the various capsids found so commonly in affected orchards. Unfortunately the presence of a species on damaged trees seems to have been regarded as sufficient evidence to record it as the cause of the trouble.

Theobald (24–28) repeatedly mentions *Atractotomus mali, Orthotylus marginalis* and *Psallus ambiguus* as the culprits. Schöyen (21) mentions *Orthotylus marginalis*, *Plesiocoris rugicollis* and *Psallus ambiguus* as doing damage in Sweden. We do not know on what evidence these statements are based as no details are given, but we have found that it is possible to visit an orchard in which the apples have been badly marked by *Plesiocoris rugicollis* after this species has disappeared and when one or more of the other three species are still present. We think therefore that very probably the damage has been attributed to the wrong species. It is of course possible that in Sweden the injury might be done by a species which is harmless in this country, but in the absence of direct evidence this should be regarded as doubtful.

Fryer has pointed out that *Plesiocoris rugicollis* is the more serious pest and has shown by direct experiment that it causes the typical damage to the leaves, and that *Psallus ambiguus* does not (12). Fryer and Petherbridge also showed by direct experiment that *Plesiocoris rugicollis* damages the fruit and shoot and that *Psallus ambiguus* and *Atractotomus mali* do not (12 *a*).

Our experiments and observations show that *Plesiocoris rugicollis* causes marked damage to the leaves, shoots and fruit and is responsible for most of, if not all, the damage in the Wisbech district, and that *Atractotomus mali, Orthotylus marginalis* and *Psallus ambiguus* although they feed on the juices of the apple do not cause any apparent damage to the varieties badly marked by *Plesiocoris rugicollis*. In no case have we found either of these three species causing any visible damage to apples.

The life-histories of a number of forms have been worked out in America (6, 7, 16, 18, 29) but very little work has been done in that direction in this country.

2. METHODS.

Observations were made during the season of 1917 chiefly in badly attacked orchards at West Walton near Wisbech where the bugs used for experimental work were also obtained. Observations were also made in unattacked orchards near Cambridge.

April 14th is the earliest record of the hatching of *P. rugicollis* (12) so we started our visits to Wisbech at the beginning of April but obtained no young capsids during the whole of this month. Twigs of apple were brought back and searched for eggs. We could not find the eggs by means of a surface examination even after cleaning the twigs with dilute potash, but were able to find them by peeling the bark when the eggs remained sticking to it. We kept a number of these twigs in water in the laboratory in the hope that young larvae would hatch out from some of the eggs. Fortunately we were rewarded by getting a number of young *P. rugicollis* larvae (one of which we observed emerging from an egg) from shoots brought in at the end of April.

These started to hatch on May 5th. Up to this date no capsid larvae had hatched at Wisbech, but a visit on May 7th revealed the presence of many newly hatched larvae. The young leaves of the shoots on which they were found were marked with brown spots.

As we were unable to identify the young capsids until later on we classified them under the headings *A, B, C,* etc. The larvae and nymphs were taken to the laboratory, carefully examined, classified and some of them measured and drawn. Some were preserved, others placed singly on shoots in cages, and others put into sleeves on apple trees, each sleeve containing a single bug. Young bugs were brought in three or four times a week and the development in the laboratory checked by the stages found at Wisbech. All the different stages found were placed on shoots in cages and sleeves and their behaviour noted. We were thus able to find out which of the species did damage and at what stages the damage was done to the leaves, fruit and young stems. Precedence was given to *P. rugicollis* in our observations as this was soon found to be the only culprit. Altogether we had over fifty cages of *P. rugicollis* and about an equal number of the other bugs. We sleeved about fifty *P. rugicollis*, and a large number of the other bugs each in a separate sleeve. We sleeved some *P. rugicollis* singly on black currants and plums, and also took some larvae and nymphs of *P. rugicollis* which were damaging black currants at Histon and sleeved them at different stages on apples.

The sleeves gave very good results and there were very few casualties. We were successful in rearing them in cages, but there were more deaths on account of their drowning or falling down at night. At first we put the twigs in beakers of water with a bug on each twig, but they often crawled down the twigs and got drowned. We then kept the twigs in small flasks of water, plugging the mouth of the flask with cotton wool and placed it in a large beaker covered at the top with a piece of muslin. These cages proved fairly successful, the chief drawback being that the bugs often fell down into the beaker and had to be replaced two or three times a day. The shoots were changed every two or three days in order to keep conditions as normal as possible. In spite of the difficulties encountered we were able to carry through to the adult stage three individuals of *P. rugicollis* which hatched in the laboratory. From the cage cases we got a complete record of the times of moulting and the duration of each instar which on comparison proved very similar to those under normal conditions at Wisbech. All doubtful cases were discarded and the figures given in Table II (p. 192) are those about which there is no doubt.

The records of the life-history in the cages in the laboratory were compared with the sleeve cases at the farm and with those under normal conditions at Wisbech and were found to agree closely, in the laboratory the hatching and certain moults were in some cases a day or so ahead. We failed to find *P. rugicollis* copulating in spite of the fact that we put males and females together on shoots in the cages. We tried to watch the process of egg laying, but in spite of careful watching we were unsuccessful. For this purpose we had lengths of glass tubing about one inch in diameter, closed at one end by a piece of muslin and at the other by a cork with a hole in it. An apple twig with a ♀ *P. rugicollis* on it was introduced in the tube and the end put through the hole in the cork; the basal end of the twig being outside was placed in water and so kept fresh. A later examination of these twigs showed that eggs had been laid. Some of these twigs with eggs were dissected and photographed.

During the early part of the experiment shoots of Bramley's Seedling, Early Victoria (Emneth Early), Grenadier, Keswick Codling, Lord Grosvenor and Worcester Pearmain were used in the cages, but later on, owing to the difficulty of getting twigs, we had no time to find out the varieties used.

P. rugicollis caused characteristic markings in every case. Details of these markings are given under the description of the injury done by this species.

Psallus ambiguus, Orthotylus marginalis and *Atractotomus mali* were at first put on shoots of Keswick Codling and Bramley's Seedling and later on several other varieties, but as far as we could see they did not change the appearance of the leaf or fruit and certainly did not cause any markings of a similar nature to those caused by *P. rugicollis*.

The drawings were done by means of a camera lucida.

A large number of measurements of the different parts are given as the length of a larva or nymph is very variable according to its food supply, a well-fed larva being much longer than a starved individual as in the latter the basal joints of the abdomen become telescoped. Owing to this we subdivided *P. rugicollis* into *A* and *B* and expected to get two different species. The measurements of the antennae and legs are not so variable.

An account of the life-histories of the various species is given below.

3. CAPSIDS FOUND ON APPLE TREES.

In this country apple trees harbour a fairly large number of the different genera of the Capsidae. From orchards near Wisbech and Cambridge we collected seven different genera and two species of one genus whilst other observers have recorded other species, e.g. *Lygus pratensis*.

The following is a list of the species found:

	District	Numbers	Remarks
Plesiocoris rugicollis	Wisbech	very abundant	affected orchards on apples and currants
	Cambridge	,, ,,	not found on apples but abundant on currants
Orthotylus marginalis	Wisbech	,, ,,	affected orchards
	Cambridge	,, ,,	unaffected orchards
Psallus ambiguus	Wisbech	,, ,,	affected orchards
	Cambridge	abundant	unaffected orchards
Atractotomus mali	Wisbech	few	affected orchards
	Cambridge	fair number	unaffected orchards
Phytocoris ulmi and	Wisbech	few	affected orchards
Phytocoris populi	Cambridge	,,	unaffected orchards
Pilophorus perplexa	Wisbech	,,	affected orchards
	Cambridge	,,	unaffected orchards
Aetorhinus angulatus	Wisbech	abundant	affected orchards
	Cambridge	,,	unaffected orchards

As pointed out above, of these eight species, *Plesiocoris rugicollis* is the only one which we have found marking the leaves, shoot or fruit and therefore we shall deal with this species in greater detail. The adults of all these genera can be easily identified (Saunders, *Heteroptera*), but it is not always possible to recognise the genus in the earlier stages.

The following characters may be useful in identifying the young stages of the above species:

Plesiocoris rugicollis hatch in April or early in May.
Yellowish green becoming greener at each successive moult.
Terminal joint of antenna pinkish brown.
Lips of dorsal abdominal gland well marked.
Mark the leaves with brown spots.

Orthotylus marginalis hatch about a fortnight later than *P. rugicollis.*
Slightly smaller, orange yellow in first stage, later greenish yellow with bluish tinge, especially marked on lower surface.
Large orange coloured dorsal abdominal gland with faint lips.
Terminal joint of antenna smoky orange. More hairy than *P. rugicollis.*

Psallus ambiguus hatch about the same time as *P. rugicollis.*
Smaller, orange yellow. Terminal joint of antenna smoky orange, and very hairy.

Atractotomus mali (Pl. X, fig. 11) hatch about a month later than *P. rugicollis.*
Small, red, two basal joints of the antenna very much thickened.

Phytocoris populi hatch nearly a month later than *P. rugicollis.*
Large. Antennae and posterior legs long. Mottled, ground colour white with yellow and brown spots; thorax with dark broad lateral bands. Antennae and legs banded and covered with long hairs.

Phytocoris ulmi differs from the preceding in being very much darker. The spots are green, brown and black.

Pilophorus perplexa. Dark reddish brown and bear a marked resemblance to ants with which they are usually found in association. Head large flattened posteriorly and overlaps the front margin of pronotum. A narrow white band across the anal margin of pronotum and a wider white band across the anal half of tergite I. Terminal joint of antenna white.

Aetorhinus angulatus hatches nearly a month later than *P. rugicollis.*
Small, slender, yellowish green, recognisable by its very long antennae and black bases of the tibeae.

4. *PLESIOCORIS RUGICOLLIS* (FIEBER).

SYNONYMY.

Lygus rugicollis Falléri. Mono. Cimi. p. 76, 1818.
Phytocoris rugicollis Falléri. Hem. Svec. 1. 79. 6.
Capsus rugicollis Schâff. Wanz iii. 80–98, Fig. 299.
Phytocoris marginalis Zelt. I. L. 271, 5.
Plesiocoris rugicollis Fieb. Eur. Hem. 272.
Reuter Cap. 2. 43.
Lygus rugicollis Doug. and Scott. E. M. M. IV. 50.

ADULT (Pl. X, fig. 10).

The genus *Plesiocoris* Fieb. consists of only one species. The adult *Plesiocoris rugicollis* is elongate oval; bright green; head, front part of pronotum, sides of elytra and legs yellow. Sparsely pilose. Elytra subparallel in ♂ and comparatively more rounded in ♀.

Head small, with large, dark red, compound eyes, nearly touching the pronotum and projecting slightly beyond its lateral margins. Vertex carinated posteriorly.

Pronotum with a very distinct narrow yellow collar and two very prominent callosities just behind it. Strongly rugose. Posterior margin not emarginate and covers the mesonotum. Sides straight.

Elytra green with yellow margin; sparsely covered with short thick almost black hairs. Membrane hyaline, two cells with green nervures and with a clouded area round the inner angle of the large cell.

Antennae medium length; covered with short thick black hairs and longer and finer light hairs; basal joint green and thicker than the other joints. Second joint longest; lower portion green, upper half dark. Terminal joint three-quarters the length of the third joint, both together shorter than the second; both dark. When cleaned and mounted in balsam terminal and sub-terminal joints pinkish brown.

Legs yellowish green, with short brownish hairs. Tibia with fine brownish spines. Tip of tibia dark and thickly covered with hairs which become thicker and longer as they approach the tip. Tarsi 3-jointed, covered with fine hairs; two basal joints sub-equal, terminal longest; tips dark with curved claws and a pair of transparent arolia.

The Egg.

Time of egg-laying.

The females of *P. rugicollis* brought from Wisbech from about the third week of June to the beginning of July were enclosed in glass tubes with apple twigs, and were observed to have laid eggs in these shoots. In spite of a careful watch, the actual process of egg-laying escaped observation. It may be that the eggs are laid during the early hours of the morning. There is no doubt that they are laid after long intervals, as in a number of cases there were only two or three eggs after a female had been on the twig for over a week. During the egg-laying period the bug keeps feeding on tender leaves and soft terminal parts of the stems which show the characteristic purple-brown spots. It would be interesting to find out the number of days that a female takes to develop eggs after fertilisation and the time taken to lay all the eggs. We are inclined to think that egg-laying continues all through the later part of the life of an adult female.

Position of eggs.

The eggs laid in the laboratory were carefully compared with those dissected out of the twigs brought from Walton, and their identity confirmed by comparison with the eggs dissected out of a female. In all cases the eggs were laid in the present year's soft stem, in many cases very near the apex and in some cases at the thickened bases of the twigs. They were laid indiscriminately in lenticels or in slits made for the purpose in other parts of the stem, preference, however, was given to a wound that had become soft, as shown by the presence of a number of eggs in such situations (Pl. IX, fig. 3). They were usually laid singly, but in some cases more than one egg was found at the same level both in lenticels and wounds. In the latter situation the number may increase to five or six.

After a little practice the position of an egg can be easily detected either as a small brown spot or a little slit in the stem, and under magnification one can easily see the brownish cap of the egg with its whitish rim (see Pl. IX, fig. 2). Only a small portion of the cap if any is above the surface of the stem. The long hairs of the stem, to a large extent, conceal the position of the egg which is often made more obscure by the hairs sticking together on account of the exudation of sap from the wound made in the stem, and by the liquid from the body of the female. After a few months the growth of green algae and particles of dust make it impossible to detect an egg by an external examination of a shoot. But if the bark is peeled off carefully the eggs may be detected on the inner side as they usually come off with it. There are no processes extending out from the egg cap.

Direction of the egg in the stem.

The eggs are laid with their long axes more or less radial to the stem and often penetrate the xylem and in young stems reach the pith. Sometimes they are more tangential and lie wholly in the bark, this is particularly the case when a number of eggs are laid at the same level with their caps close to each other on the surface. They lie somewhat obliquely with their concave side facing the apices of the twigs and the blunt end situated in front of the cap (see Pl. IX, fig. 1). Only in one case was an egg found with its convex side towards the apex of the twig (Fig. 3). The greatest diameter of the egg cap is in line with the long axis of the shoot and only in one case when the egg was laid in the scars of the previous year's bud scales was the long axis of the egg cap at right angles to the long axis of the stem. This can be explained on simple mechanical grounds. The female must have a strong hold on the stem for the action of its ovipositors and for this it seems necessary that she should hold on in the direction of the stem and not crosswise. Moreover it is easier to separate the fibres of the xylem than to cut across them and a longitudinal slit does not interfere with the growth of the surrounding parts and the egg remains in a fresh condition. The tissue around the egg remains in a healthy condition, except probably around the collar of the egg.

From the position of the egg it would appear that the female faces the base of the twig when ovipositing, and this is borne out by the structure of the ovipositor which is concave on the dorsal side [i.e. posterior side when ovipositing] and by actual observation on the position of an egg which was carried about by a female (its laying in tissue somehow or other interfered with) with its convex side directed ventrally. The direction of the egg shows that the ovipositor acts almost vertically to the stem only a little upward in direction. We cannot suggest any reason for the female facing towards the base of the shoot for oviposition.

Structure of the egg.

The egg has been described by Fryer (12) as somewhat resembling the rubber portion of a fountain pen filler. It is markedly curved along its length, with one end bluntly rounded and thick, and gradually narrowing towards the opposite end forming a neck-like region and slightly expanding into a cap at the top end (see Pl. IX, fig. 4 *A*). The egg is cream coloured, the surface is smooth and glistening and the shell is strong and elastic. The body of the egg is slightly flattened by the fibres of the plant pressing against it. This part of the egg is thus oval in cross-section becoming almost circular in the region of the neck. The cap is dark brown in colour and strongly chitinized. It shows strongly marked longitudinal striations all round, which are probably hairs that hold the cap to the egg-shell and at the base of it are seen a few scale-like markings. The function of these markings is obscure. The opening of the egg is closed by a strong oval disc, brown in colour and showing curious processes on both surfaces. The outer rim of the cap is whitish with radially arranged lamellar-like structure when seen from above.

As mentioned above, the egg dissected out of a twig is flatter than one dissected out of a female. It measures 1·4 mm. in length, 0·3 mm. at its greatest width, and 0·25 mm. in the region of the neck.

In the body of a mature female the eggs lie in longitudinal direction, all with their caps pointing forwards. The whole body is practically full of eggs, which reach right up to the prothorax. The largest number dissected out of one female was fourteen, but it is probable that the actual number is more than this.

The eggs live in the shoots all through the winter and the young larvae hatch from them the following April or May.

DESCRIPTION OF THE INSTARS.

Instar I (Pl. IX, fig. 5). Length 1·1–1·4 mm., small, slender, fragile, semi-transparent. When just hatched pale yellow, turning greenish and darker in a few hours. On the head and thorax are smoky patches interrupted on the thorax by a mid-dorsal pale line which bifurcates on the head at the level of the eyes. The smoky colour is in the chitin whilst the actual colour of the bug is due to pigments in the tissues of the body.

Head relatively large, marked longitudinal groove just in front of vertex; yellow, with smoky shades interrupted by a Y-shaped pale line. A row of short thick black hairs is present on the vertex and a few longer hairs on the front of the head. Eyes, compound, large, deep carmine in colour, nearly touching the pronotum.

Thorax increases in width up to the metathorax.

Pronotum almost rectangular, anterior margin slightly curved, angles rounded. Light green with smoky patches interrupted by mid-dorsal pale line. Row of hairs on posterior margin and a few irregularly scattered hairs.

Mesothorax with smoky patches; broader than prothorax.

Metathorax shortest and broadest, smoky patches narrower.

Abdomen pyriform, slightly longer than broad; greatest breadth across segments II–IV. (In a well-fed individual the abdomen is distended and almost circular in cross-section; but in a starved specimen it becomes flatter and the first two abdominal segments become telescoped.) Yellowish green, with a pale line extending from segments III–X, smoky patch on segment I. A large circular yellow area is present in the mid-dorsal region of segment III. This is the pocket-shaped dorsal abdominal gland seen through the cuticle; its orifice is between segments III and IV; the anterior lip is the black thickened part of the anal margin of tergite III. The anterior part of tergite IV opposite this is dark and the two lips enclose a light coloured area. A row of thick short black hairs on each tergite, longer on segments VIII–X; segment IX also has a number of small hairs. Whole abdomen covered with a fine fur of setae.

Appendages.

Antennae medium-sized, slender, at first pale yellowish green, later dusky. Terminal joint yellow at base, changing into orange, pinkish brown, orange and yellow towards the tip. This pinkish brown colour is characteristic of all the instars of this species. Terminal joint longest; 1½ times that of the third joint and slightly thicker. It is thickly covered with hairs, other joints fewer hairs.

Legs short, thick, at first pale, then turn yellowish green and dusky, tarsi almost black. Femora light green with a few black hairs slightly longer than those on the body. Tibia slender with more and longer hairs. Tarsi 2-jointed, the terminal joint being the longer. Two black curved claws with transparent aroliae.

Proboscis greenish yellow with a black tip; reaches to about the middle coxae.

Instar II (Pl. IX, fig. 6). Length 1·5–2·2 mm. Resembles Instar I in shape. At first yellowish with transparent appendages but soon becomes darker. The body is distinctly greener than Instar I. The smoky shades present on the head, thorax and abdomen are now absent. The pale mid-dorsal line on the abdomen and thorax bifurcating on the head is still present.

Characteristic differences. Nearly double as long. Terminal joint of antenna slightly longer than joint II; joint II distinctly longer than joint III. Posterior margin of mesonotum slightly emarginate.

Head large, no groove present; yellow with Y-shaped pale line present. Eyes deep red, and the number of facets has increased.

Thorax, shape as Instar I.

Pronotum trapeziform, anterior margin slightly narrower than the posterior; two callosities present.

Abdomen pyriform; longer than broad. No smoky shade on segment I. The yellow mid-dorsal abdominal gland is still present on segment III and its lips are well marked.

Appendages.

Antennae medium sized, slender—colour as in Instar I; basal joint thickest; terminal joint longest, slightly longer than joint II.

Legs similar to Instar I but longer.

Proboscis reaches to about the middle coxae, colour as in Instar I.

Instar III (Pl. X, fig. 7). Length 2·1–2·8 mm. Outline and colour as Instar II; mid-dorsal line faint.

Characteristic structural peculiarities. The second joint of the antenna has increased relatively more than the other joints. Terminal joint of antenna now shorter than the second joint which is the longest; the third joint shorter than the fourth. Wing pads, small thickened lobes at the posterior angles of meso- and metanotum, the former being slightly larger. The wing pads become darker when the nymph is about to moult. Other characters similar to Instar II, the yellow spot on the abdominal segment III being rather faint.

Instar IV (Pl. X, fig. 8). Length 1·33–1·99 mm.

Characteristic structural peculiarities. A further increase in the relative

TABLE I. *PLESIOCORIS RUGICOLLIS* (MEASUREMENT IN MILLIMETRES).

		Instar I	Instar II	Instar III	Instar IV	Instar V	Adult
Head	Length	·21	·34	·43	·52	·54	·56
	Width	·4	·52	·64	·79	·9	·99
	Distance between eyes	·26	·34	·39	·45	·5	·5
Prothorax	Length	·21	·26	·31	·4	·6	—
	Width	·38	·55	·69	·86	1·15	—
Mesothorax	Length	·14	·19	·28	·43	·67	—
	Width	·48	·6	·86	—	—	—
Metathorax	Length	·12	·14	·17	·17	·19	—
	Width	·49	·66	·88	—	—	—
Wings	Length	—	—	—	·85	1·7	—
	Width	—	—	—	1·4	1·8	—
Abdomen	Length	·43–·73	·8–1·29	1·1–1·47	1·33–1·9	1·9–2·37	—
	Width	·57	·69	·95	1·3	1·7	—
	Total length	1·1–1·4	1·5–2·2	2·1–2·8	2·7–3·4	3·6–4·27	5·9–6·0
Antennae	1	·14	·17	·22	·29	·38	·55
	2	·20	·34	·54	·86	1·3	1·81
	3	·17	·26	·40	·57	·76	·91
	4	·31	·40	·45	·52	·57	·70
	Total length	·82	1·17	1·61	2·24	3·01	3·8
Leg I	Femur	·25	·41	·52	·69	·78	1·29
	Tibia	·34	·46	·66	·83	1·1	1·6
	Tarsus	·19	·24	·28	·34	·43	·58
Leg II	Femur	·31	·46	·6	·83	1·1	1·48
	Tibia	·38	·55	·78	1·09	1·48	1·82
	Tarsus	·2	·25	·28	·39	·5	·62
Leg III	Femur	·36	·47	·69	·94	1·2	1·85
	Tibia	·45	·69	·98	1·5	1·95	2·92
	Tarsus	·22	·29	·34	·45	·55	·68
Rostrum	1	·16	·20	·26	·32	·41	·49
	2	·13	·18	·21	·27	·34	·44
	3	·1	·13	·16	·24	·31	·42
	4	·18	·21	·27	·32	·41	·53
	Total length	·56	·70	·87	1·1	1·39	1·84

length of the second antennal joint; the third joint is now longer than the fourth. A change in the shape of the thorax, owing to the increase in size of the wing pads which now reach the second abdominal segment. Other characters as in Instar III.

TABLE II. *PLESIOCORIS RUGICOLLIS.*

Stages	Dates of hatchings and of the various instars	Duration of each instar	Records of hatchings and moults obtained in the laboratory	
Hatching	*May 5th–13th	—	—	—
Instar I	present from May 5th–18th	6 days	Hatching	1st moult
			5. v. 17	11. v. 17
			5. v. 17	11. v. 17
			5. v. 17	11. v. 17
Instar II	present from May 11th–23rd	4–5 days	1st moult	2nd moult
			11. v. 17	14. v. 17
			11. v. 17	15. v. 17
			11. v. 17	15. v. 17
			12. v. 17	16. v. 17
			12. v. 17	17. v. 17
Instar III	present from May 15th–28th	6 days	2nd moult	3rd moult
			14. v. 17	20. v. 17
			15. v. 17	21. v. 17
Instar IV	present from May 20th–June 3rd	5–7 days	3rd moult	4th moult
			20. v. 17	26. v. 17
			20. v. 17	25. v. 17
			24. v. 17	30. v. 17
			24. v. 17	31. v. 17
			25. v. 17	31. v. 17
			31. v. 17	6. vi. 17
Instar V	present from May 25th–June 9th	6–7 days	4th moult	5th moult
			25. v. 17	1. vi. 17
			28. v. 17	4. vi. 17
			31. v. 17	6. vi. 17
Adult	present from June 1st–July 21st	about 6 weeks	—	—

* Fryer records these larvae as hatching before April 14th in 1913.

Instar V (Pl. X, fig. 9). Length 1·9–2·37 mm.

Characteristic peculiarities. Colour greener than in previous stages; second joint of antenna very long, nearly equal to the third and fourth together. Wing pads larger and reach the fourth abdominal segments. Yellow spot on abdominal segment III not noticeable. Other characters as in Instar IV.

HABITS.

Plesiocoris rugicollis hatches out after the buds of the apple have opened and about 16–17 days before the flowers are in full bloom. Very soon the young larvae move to the opening buds and begin to feed on the tender opened or half-opened leaves which at this stage are not more that about an inch in length. On the opened leaves they usually feed from the upper surface more especially on each side of the mid-rib of the basal half of the lamina (see Pl. XI, fig. 12). They also feed on the upper surface of the rolled opening leaves and here they are partially concealed. Every leaf where they feed soon shows the characteristic brown spots. On being disturbed they run away very quickly and conceal themselves either in the curled leaves or the axils of the opened leaves. It is difficult to shake them off a branch at this stage, even when falling from one of the upper branches of a tree they hardly ever reach the ground but obtain a hold on one of the lower twigs either by means of their sharp claws or by extruding the posterior part of their alimentary canal which secretes a sticky fluid. The hairs on the leaves and stems of the apple seem to help them in regaining their hold as they are more easily shaken off the black currant. The later instars are more easily shaken off. At all stages they run very quickly but seem to be more active during the younger stages. They dodge like a squirrel by running to the opposite side of the stem and it is often difficult to catch them.

They share with other insects the habit of cleaning their antennae by means of the hairs at the ends of the front tibiae after which they often rub their tibiae against each other. They moult in any situation, cast skins having been found on both surfaces of the leaves, on the petioles and on the stems. When ready to moult they become very sluggish and stop feeding. Moulting takes place by a longitudinal slit in the mid-dorsal region of the thorax, this being preceded by a throbbing in the region of the callosities on the pronotum. The thorax and part of the head and abdomen come out first, followed by the legs and antennae and lastly by the rostrum. After moulting the bugs feed voraciously, making repeated stabs at the leaf at the rate of about fifty per hour.

The adults are easily shaken from the trees.

In walking through an infested orchard we have never seen them flying from one tree to another, but they can fly a fair distance when disturbed. When shaking them from a tree into a Bignell beating tray they often fly back again into the tree before reaching the tray and some of those which reach the tray fly back to the tree again. In the laboratory they usually flew towards the window in an almost horizontal direction, but some flew upwards and a few reached the ceiling.

TIME AND NATURE OF INJURY.

In 1917 a very severe and prolonged winter was followed by a warm spring, the former retarding the opening of the buds and also the hatching of *P. rugicollis*. Fryer records them as hatching before April 14th in 1913 and in 1916 a few newly hatched bugs were found on April 25th. In 1917 the first markings were seen on May 7th, but under warmer conditions in the laboratory a few hatched on May 5th. At this date the buds were opening rapidly, the diameter of well-opened buds being about one inch and a half, with the outer leaves about an inch long. The first attack started immediately after hatching and in a day or two a large number of buds showed the characteristic purple brown markings on their leaves. The number of attacked buds continued to increase rapidly on account of new larvae which kept hatching until May 13th and also because the earlier hatched larvae moved from one bud to another. It is probable that the hatching period, May 6th–May 13th, is shorter than the normal period owing to the warm condition obtaining at this period in 1917.

In some varieties and notably Lord Derby the leaves remained curled much longer than in other varieties and provided more shelter for the bugs. The time of full bloom of Early Victoria, Lord Grosvenor and Lady Hollendale was on May 23rd, i.e. about seventeen days after the bugs started to hatch and during this time the leaves were the source of food. In some varieties, e.g. Grenadier, the opened leaves were soon used up as a source of food and were very badly damaged, the bugs then began to feed on the closed part of the buds. This variety received a very bad check from the marking of the young leaves which did not expand to any extent (see Pl. XI, fig. 14 B).

When the fruit set the bugs were mostly in the fourth instar, some third and fifth instars also being present. These bugs began to mark the fruit on May 28th, very soon after setting. All the last three nymph stages and the adults damage the fruit. In cages in the laboratory they did not show any marked preference for the fruit but fed upon leaves and fruit alternately and seemed to be quite satisfied to feed at the place where they were put, except on old leaves.

They did not attack the fruit after it was over an inch in diameter but turned their attention to the young leaves and succulent part of the stem. When the adults appear the fruit is a fair size and not much damage is done to it by them, but the adults do most of the damage to the shoots. Where the young stem is attacked a brown fluid oozes out, the stem often cracks and is in some cases killed. When the terminal shoot is killed several of the buds below form shoots and a very thick tree results, especially when young trees are attacked. Most of the damage to the fruit is done by the Instars IV and V.

Wherever a *P. rugicollis* in any stage sucks a leaf a purplish brown spot appears after a short time, at first round but soon becoming irregular. The spot becomes irregular by spreading to the nearest small veins which form the boundaries of the spot and thus the shape of the marking is determined by the small veins between which the puncture is made. The area covered by the spot becomes thinner and sinks below the normal level of the surface of the leaf.

In older leaves the marking does not spread much but remains as a small spot. In all cases cork formation takes place round the seat of injury. When the puncture is very deep the whole of the mesophyll is affected, but in some punctures from the upper surface only the upper part of the mesophyll was injured and in some punctures from the lower surface only the lower part of the mesophyll turned brown. In many cases the epidermis over the brown spot appeared to be normal. Sections of injured leaves show that the mesophyll dies first and the epidermis afterwards. A badly damaged leaf sometimes remains shrivelled and eventually dies. Some badly damaged leaves do not die but remain crumpled and deformed, the dead tissue falling out and leaving a number of holes with a brown margin. In several trees of the variety Grenadier the leaves were so badly punctured that very little growth was made until late in the season. In a mild attack the leaves may grow fairly well whilst showing the small brown marks. Occasionally a vein is punctured and a brown spot results.

The injury to the fruit varies with the variety. In the slower growing varieties like Lady Hollendale and Worcester Pearmain the damage is enormous and badly marked apples do not grow even to one-quarter of their normal size and often fall off. In the quicker growing varieties like Bramley's Seedling and Early Victoria the fruit grows out of the injury more, and although corky markings and peculiar shaped apples may result, the reduction of the crop is not nearly so marked.

When a bug punctures the young fruit a small drop of fluid exudes from each puncture. These drops eventually dry up and leave a brown mark in the fruit (see Pl. XI, fig. 13). The tissue around the seat of injury forms cork and is therefore prevented from making normal growth, dimpled or malformed fruit resulting. In a young apple the injury extends several cells below the cuticle, but in an old apple there is no discoloration of the flesh under the cork layer.

Punctured apples in their late stages show a russetting due to the brown cork scars and in some varieties they crack badly. Practically all the damage to the fruit is done before it reaches an inch in diameter, probably because later on it is too hard to be easily punctured. In one or two cases adults were found dead with their probosces inserted into the tissue of medium-sized fruits. Cork formation follows the punctures in leaves, fruit and young shoots.

THE CAUSE OF INJURY.

It has been suggested (1, 14) that the injury done by a capsid is due to the mechanical laceration of the tissues by the barbed stylets of its rostrum. There is no doubt that the ends of the stylets are barbed and that the bug does puncture the plant repeatedly, but how far this laceration is responsible for the brown spots or any other external sign of damage is difficult to say. A number of different capsids were found feeding on the same trees but only in the case of *P. rugicollis* was any visible damage done.

The stylets of all these capsids are very similar and it seems to us that the cause of the damage is chemical rather than mechanical, the salivary injection from *P. rugicollis* being lethal to the tissue of apple trees whilst that of the other species is not. This is supported by the fact that it is the mesophyll and not the epidermis which shows the first signs of injury, and dead mesophyll may be present under a healthy epidermis, and again the damaged area may spread for some time after laceration has taken place.

This brings us to an interesting biological problem. The injury done to a plant may be mechanical or physiological, and although the final result to the plant may be the same it seems necessary to distinguish these two kinds. The term "mechanical injury" might be used to include the wounding of plants by eating away parts of them or by sucking the juices. The term "physiological injury" might mean the injection of some material into the plant which kills the tissue or brings about abnormal growth. The same species might be responsible for both mechanical and physiological damage.

It seems probable that in the case of *Plesiocorus rugicollis* the mechanical injury is of little consequence. *Psallus ambiguus* and *Orthotylus marginalis* were sometimes as numerous as that species and yet the injury caused by their sucking the juices was of no importance. An insect that causes mechanical injury would probably do so to all plants that it feeds on but it is possible that the injection of an insect that causes physiological injury might affect different plants in different ways and even be harmless to some plants and also much less harmful to some varieties of plants of the same species.

It is interesting to find that certain pests are specific in their attacks whereas others infect a large number of plants. *Lygus pratensis* is known to attack fifty different species of plants (7). *Plesiocoris rugicollis* was formerly known to attack *Salix* and *Alnus* but it now attacks apple, black and red currants and under experimental conditions has been made to attack plums. This interesting change in the diet of a species is possibly comparable with mutations in the morphological characters and may be due to some physiological mutation in the organism. It is possible that *P. rugicollis* may in the future extend its host plants and so become a still more serious pest.

The change in its diet is difficult to explain but it may be due to a very simple cause. Larvae cannot fly and when just hatched do not appear capable of travelling far, and their only chance of living seems to be to suck the juice of the plant on which the eggs are laid. They get used to this diet and so do not change it readily. Suppose a fertilised female to be blown on to a new host and not capable of reaching her former host, she may lay eggs there and if she can live on the juices of this host the larvae which hatch from these eggs will probably be able to live on the tissues of the host on which their mother could live, and in any case are unable to reach the original host of their mother. Actual experimental evidence is wanting, but we know that nymphs can be made to change their hosts, e.g. apple to plum, and black currant to apple, and it would be interesting to see if *P. rugicollis* could be made to lay eggs on a species other than that on which it was reared.

The facts that apples and willows are found interlacing and only the willows attacked by *P. rugicollis* and also apples and black currants interlaced with only the latter attacked show that it normally lays its eggs on the host on which it has fed and does not readily change its host when that host is capable of providing it with food.

In the Wisbech district *P. rugicollis* lives on willows, apples, black currants and red currants, whereas in certain districts near Cambridge it does not live on apples but does on the other three. Larvae from black currants near Cambridge were sleeved on apple trees and although they did not feed readily at first eventually became used to their new host and completed their development. They begin to feed more readily if transferred in the early larval stages than in the later stages. Larvae from apples also reached the adult stage when sleeved on black currants. In an orchard at Great Eversden where for several years black and red currants have been attacked, this year the rows of apples near them, Worcester Pearmain, are also attacked.

The black currant leaves are much thinner than apple leaves and consequently the brown marks caused by the bugs soon fall out and leave holes with a brown margin.

Larvae of *P. rugicollis* when sleeved on plum caused a few markings but did not live long. The injury was similar in appearance to that of black currant.

Taylor (23) and Collinge (5) attribute the dimples in apple fruit to the eggs of *Lygus pratensis* which are also laid in the stalk of the fruit which may consequently fall off. This is not the case with *P. rugicollis*.

Control.

It has been shown by experiments (12, 12*a* and some carried out in 1917 by one of us) that *P. rugicollis* can be kept in check by spraying with "soft soap and nicotine." The amount of soft soap necessarily varies with the hardness of the water, 1·0 per cent. or even less is sufficient for soft water but it may be better to use more than this for hard water. 0·05 per cent. of nicotine (98–99 per cent.) is sufficient. This wash kills the bugs very quickly in all stages except the egg stage.

In order to have its maximum effect the wash should be applied just after all the bugs have hatched and spraying may continue for some time after the fruit has become marked. It is necessary to spray with a powerful jet and for this purpose a high pressure pump and a fairly coarse nozzle should be used. The trees should be thoroughly drenched and sprayed in a *downward* direction, keeping the nozzle fairly close to the opening leaves.

As the eggs are laid in the young shoots, trees from an infested nursery should not be planted in non-infested areas.

5. SUMMARY OF THE LIFE-HISTORY OF A CAPSID.

Although these bugs do not undergo a sudden change at any moult, yet each stage possesses characteristic features. The following is a brief summary of these peculiarities founded on the study of the capsids dealt with in this paper and others that have come under our notice and will be applicable to a large number of species.

Instar I. Smoky shade on dorsal surface of head, thorax and first abdominal segment, interrupted in the region of the thorax by a mid-dorsal pale line which continues on the head and bifurcates at the level of the eyes (see Pl. IX, fig. 5).

Longitudinal groove present on the head.

Terminal joint of antenna the longest.

Instar II[1] (Fig. 6). No smoky shade.

Terminal joint of antenna slightly longer than the second.

No wing pads.

Instar III (Pl. X, fig. 7). Small but distinct wing pads.

Second joint of antenna the longest.

Instar IV (Fig. 8). Wing pads reach second abdominal segment.

Second antennal joint relatively longer.

Instar V (Fig. 9). Wing pads reach fourth abdominal segment.

Second antennal joint still longer.

All these instars have 2-jointed tarsi.

6. *ORTHOTYLUS MARGINALIS* REUT. (*NASSATUS* FALL. ET AUCT.).

This species hatches about a fortnight later than *P. rugicollis* and *Psallus ambiguus*. The adult resembles *P. rugicollis* in its green colour but can be readily distinguished from it by the absence of a collar and the two callosities on the pronotum; it is moreover covered with fine white hairs. The eyes nearly touch the pronotum.

The antennae are slender, medium sized, with the basal joint somewhat pale in both sexes, and the terminal joint with no pink colour.

A very distinct orange spot is present between the last two pairs of coxae.

Male with asymmetrical genital forceps, that of the left side having two conspicuous prongs.

It is mentioned by Theobald (24, 28) and Schöyen (21) as a pest of apples but we find no evidence for this. We have found it in considerable numbers in uninjured orchards.

The egg of *Orthotylus marginalis* is smaller than that of *P. rugicollis*, being only 0·95 mm. in length. It resembles the rubber part of a fountain pen filler with the open end flattened laterally.

It differs from the egg of *P. rugicollis* in that the transverse section of the cap is much longer than it is wide and the cap itself is convex.

It is slightly curved in the region of the neck (cf. Pl. IX, figs. 4 A and B).

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[1] Crosby and Leonard's (7) third and fourth stage are alike and what they describe as second stage is really the third.

We dissected out eggs from a female but did not find any eggs in the stems. Females were put on shoots in cages but we were unable to find any eggs in these shoots.

The eggs are undoubtedly laid in the stems because the larvae hatch out on the twigs.

Instar I. Length 1·17–1·26 mm.

In shape very similar to Instar I of *P. rugicollis* but smaller and distinguishable by the bright orange-yellow dorsal abdominal gland, which

TABLE III.

ORTHOTYLUS MARGINALIS (MEASUREMENTS IN MILLIMETRE).

		Instar I	Instar II	Instar III	Instar IV	Instar V	♂	♀
Head	Length	·24	·31	·39	·52	·55	·58	·6
	Width	·38	·5	·63	·79	·90	·94	1·02
	Distance bet. eyes	·2	·28	·39	·45	·52	·44	·52
Prothorax	Length	·17	·24	·31	·39	·58	·85	—
	Width	·4	·55	·66	·83	1·2	1·3	—
Mesothorax	Length	·13	·18	·25	·41	·62	—	—
	Width	·45	·66	·85	—	—	—	—
Metathorax	Length	·08	·11	·15	·17	·17	—	—
Wings	Length	—	—	—	—	1·6	4·8	—
	Width	—	—	—	1·2	1·9	2·1	—
Abdomen	Length	·55–·69	·76–·95	·86–1·16	1·3–2·0	1·9–2·0	—	—
	Width	·48	·75	1·0	1·1	1·5	—	—
	Total length	1·17–1·26	1·6–1·8	1·9–2·4	2·7–3·5	3·9	6·23	—
Antennae	Segment 1	·1	·13	·18	·28	·39	·50	
	,, 2	·17	·26	·46	·82	1·3	1·85	
	,, 3	·13	·22	·34	·58	·79	1·02	
	,, 4	·25	·31	·39	·47	·55	·66	
	Total length	·67	·96	1·37	2·12	3·33	4·03	
Leg I	Femur	·24	·37	·5	·7	1·0	1·25	
	Tibia	·26	·4	·57	·8	1·1	1·46	
	Tarsus	·15	·18	·25	·29	·38	·46	
Leg II	Femur	·24	·4	·5	·82	1·1	1·46	
	Tibia	·29	·45	·63	·94	1·3	1·72	
	Tarsus	·15	·18	·25	·32	·41	·47	
Leg III	Femur	·29	·45	·56	1·0	1·5	2·00	
	Tibia	·34	·6	·93	1·4	2·0	3·00	
	Tarsus	·17	·27	·31	·40	·52	·63	
Proboscis	1	·18	·2	·24	·34	·44	·51	
	2	·08	·15	·19	·27	·36	·44	
	3	·07	·12	·17	·23	·29	·40	
	4	·17	·19	·21	·29	·37	·42	

is easily seen by the naked eye through the chitin. Lips of this gland very light brown and not so noticeable as in *P. rugicollis.*

Yellowish green in colour, eyes dark red with a white margin round them. Thorax and abdomen covered with long white hairs. Antennae light orange with a dusky chitin; terminal joint of same colour, not pink as in *P. rugicollis.* Other characters typical of first Instars (see p. 199).

Instar II. Length 1·6–1·8 mm.

Peculiarities typical of Instar II (see p. 199), otherwise as Instar I except for a slight bluish tinge, especially underneath.

Instar III. Length 1·9–2·4 mm.

Peculiarities typical of Instar III (see p. 199), otherwise as previous instar.

Instar IV. Length 2·7–3·5 mm.

Peculiarities typical of Instar IV (see p. 199), otherwise as previous instar.

Instar V. Length 3·9 mm.

Peculiarities of Instar V (see p. 199), otherwise as previous instar.

The last three instars have a definite bluish tinge.

7. *PSALLUS AMBIGUUS* (FALL.) (*OBSCURUS* D. AND S.).

This species hatches out about the same time as *P. rugicollis.* A large number were found in the orchards at West Walton. They are very shy during the first two stages and lie concealed in the axils of the leaves and it is very difficult to see them and still more difficult to dislodge them by beating or shaking. They were found equally frequently in damaged and undamaged buds, and their behaviour in cages and in sleeves definitely proved that these were not associated with the injury done to the leaves and fruit. They were present at the University Farm, Cambridge, and at Histon where there was no trace of damage. We found them too frequently on apple shoots brought for our cages, but never found any damage on these and consequently we regard this species as harmless. One fact is very significant and requires elucidation. As pointed out above the larvae of *Psallus ambiguus* lived for weeks on absolutely dried shoots with no leaves and several of them reached the fourth instar stage. This suggests that their source of food may be something other than plant juices. There were present on these twigs, eggs and nymphs of the apple sucker (*Psylla mali*) and also eggs and young of the red spider (*Tetranychus* sp.). There is no doubt that they do suck plant juices as we have seen them doing so, but we have also seen them sucking the dead bodies of other capsids and it seems probable that they may be carnivorous and consequently beneficial.

The duration of each instar is very much the same as in the case of *P. rugicollis.*

Instar I. Length 1·0–1·4 mm.

Yellow, eyes crimson with a white edge round them.

Thorax and abdomen covered with long white hairs.

TABLE IV. *PSALLUS AMBIGUUS* (MEASUREMENTS IN MILLIMETRES).

		Instar I	Instar II	Instar III	Instar IV	Instar V	Adult
Head	Length	·24	·31	·35	·4	·43	·43
	Width	·37	·48	·57	·69	·8	·86
	Distance between the eyes	·28	·31	·34	·4	·45	·45
Prothorax	Length	·17	·26	·29	·43	·48	·72
	Width	·37	·51	·59	·76	1·0	1·6
Mesothorax	Length	·12	·17	·25	·37	·57	·81
	Width	·45	·6	·68	—	—	—
Metathorax	Length	·11	·12	·13	·15	·15	—
	Width	·51	·67	·75	—	—	—
Wings	Length	—	—	—	·77	1·4	3·41
	Width of body in the region of wings	—	—	—	1·1	1·5	1·8
Abdomen	Length	·48–·62	·8–·88	·94–1·1	1·3–1·6	1·7–1·9	—
	Width	·56	·68	·85	1·2	1·4	—
	Total length	1·0–1·4	1·6–1·8	2·1–2·3	2·6–3·1	3·28–3·6	4·5
Antennae	1	·07	·14	·16	·2	·28	·36
	2	·15	·28	·4	·6	·85	1·17
	3	·13	·22	·31	·4	·52	·58
	4	·25	·31	·28	·32	·36	·4
	Total length	·60	·95	1·15	1·52	2·11	2·51
Leg I	Femur	·27	·34	·41	·54	·7	·9
	Tibia	·3	·36	·5	·54	·81	1·1
	Tarsus	·16	·19	·22	·27	·3	·36
Leg II	Femur	·28	·36	·51	·63	·9	1·0
	Tibia	·32	·43	·58	·72	1·1	1·4
	Tarsus	·16	·19	·23	·28	·35	·38
Leg III	Femur	·39	·41	·63	·8	1·1	1·4
	Tibia	·43	·5	·79	1·1	1·62	2·1
	Tarsus	·19	·23	·28	·36	·49	·58
Proboscis	1	·16	·20	·27	·3	·41	·45
	2	·12	·15	·19	·27	·38	·41
	3	·09	·12	·18	·23	·30	·36
	4	·18	·21	·27	·3	·40	·45

Yellow dorsal abdominal gland with faintly marked lips.

Antennae pale orange with a dusky shade in the chitin; terminal joint of same colour, not pink as in *P. rugicollis*.

Other characters typical of first Instars.

Instar II. Length 1·6–1·8 mm.

Peculiarities typical of Instar II (see p. 199), otherwise as Instar I.

Instar III. Length 2·1–2·3 mm.

Antennae darker, basal joint darkest.

Head yellow; thorax and abdomen greyish yellow with a green tinge.

Eyes dark red with a white margin.

Peculiarities typical of Instar III (see p. 199), otherwise as Instar II.

Instar IV. Length 2·6–3·1 mm.

Peculiarities typical of Instar IV (see p. 199), otherwise as Instar III.

Instar V. Length 3·28–3·6 mm.

Peculiarities typical of Instar V (see p. 199), otherwise as Instar IV.

Adult. Length 4·5 mm.

Oval; ♂ dark brown; ♀ varies from grey to dark brown, cuneus always reddish.

Body covered with long pale hairs which easily rub off.

No collar on pronotum.

8. *ATRACTOTOMUS MALI* (MEY.).

This species has been accused of doing great damage to the apple in Suffolk and Hereford (26) but in all our experiments we have found it to be quite harmless. It was not found in any great numbers either at Wisbech or at Cambridge, but the trees on which they were found in fair numbers, two or three on one shoot, showed no marks or signs of injury. While one *P. rugicollis* larva would cover two or three fair sized leaves with brown spots in one night, two even three or four nymphs kept in cages for days on the same shoot did not mark them. We regard this species as quite harmless.

Instar V (Pl. X, fig. 11). Small, broad, ovate nymph, with deep dark red colour, very dark on the anterior part of pronotum, wing pads and two basal antennal joints.

Antennae medium sized with two basal joints very thick and dark red, thickly covered with black hairs.

The two terminal joints cream coloured with a faint tinge of orange in the terminal joint.

Femora red, tibiae upper half red, lower half and tarsi pale.

Proboscis reaches the second coxae.

Peculiarities typical of Instar V.

9. THE ENEMIES OF CAPSIDS.

We gave very little attention to this side of the subject but we never found any insect attacking capsids. We found a cimicid *Anthocoris sylvestris* sucking the dead bodies of capsids at various stages and we also saw several species of capsid sucking the dead body of the same or different species. It is possible that *Anthocoris sylvestris* and also some species of capsids, e.g. *Psallus ambiguus*, are capable of killing live capsids, but we have never observed them doing so.

The young capsids are so active except at moulting that they would probably escape from such enemies as those which attack aphis. We found dead capsids on the trees and on healthy shoots in cages but we were unable to assign a causal organism.

10. THE FOOD OF APPLE-DWELLING CAPSIDS.

Both the nymphs and adults of *Plesiocoris rugicollis* live mainly on the juices of the leaves, stem and fruit of various species of plants, but they have been seen sucking dead individuals of the same or another species. Where they suck another bug a blackish mark is formed. This is also true of *Psallus ambiguus, Orthotylus marginalis, Atractotomus mali* and larvae of *Phytocoris ulmi*. *Atractotomus mali* has been recorded as attacking caterpillars of Hyponomeuta (13, 20), and in one case we found a large number of adults near a nest of these caterpillars. Such large numbers were never found together in any other place.

Psallus ambiguus feeds on plant juices but it can live for several weeks on dried twigs on which nymphs and adults of *Psylla mali* and young forms of *Tetranychus* sp. were present. No definite observations were made as to its carnivorous nature, but Rymer Roberts writes that "a nymph of *Psallus ambiguus* fed on *Aphis avenae* and also on two syrphid eggs."

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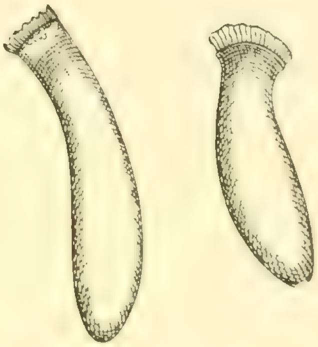

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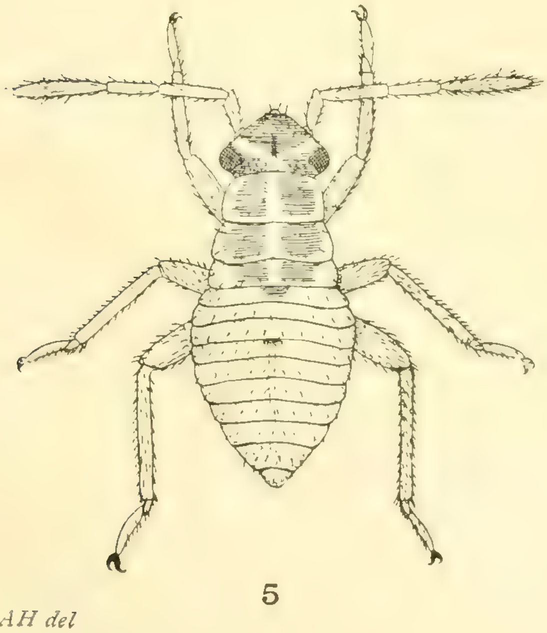

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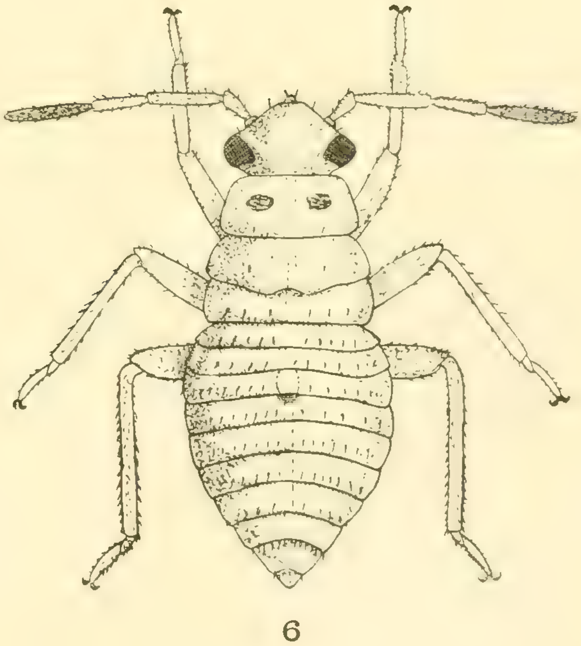

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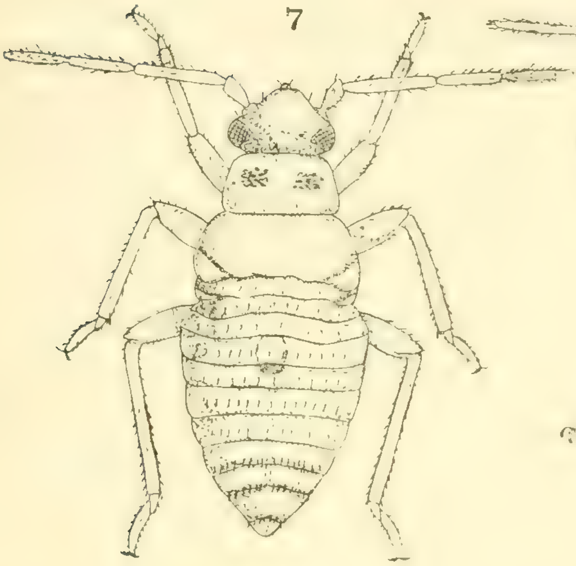

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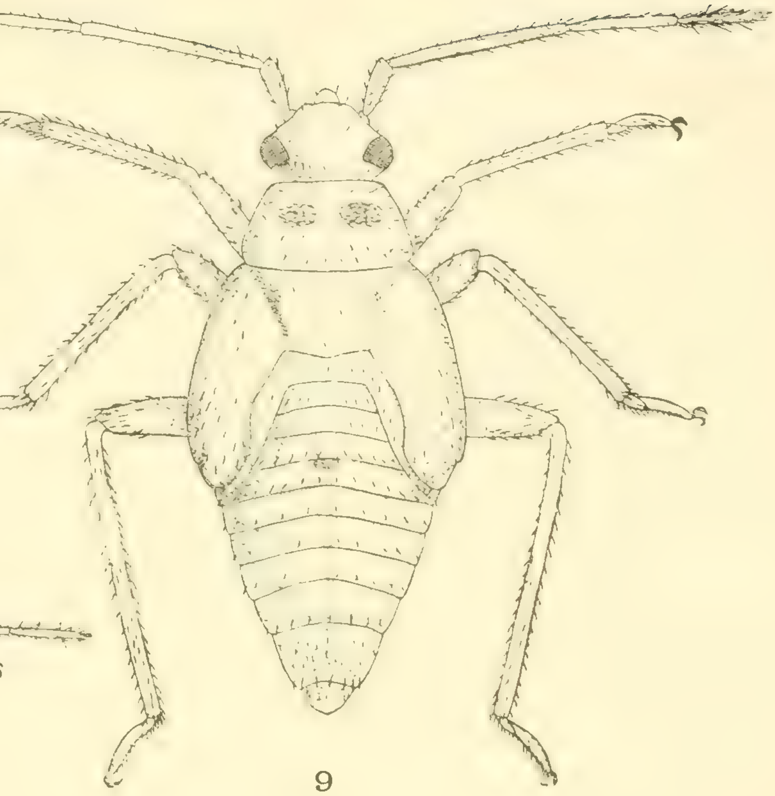

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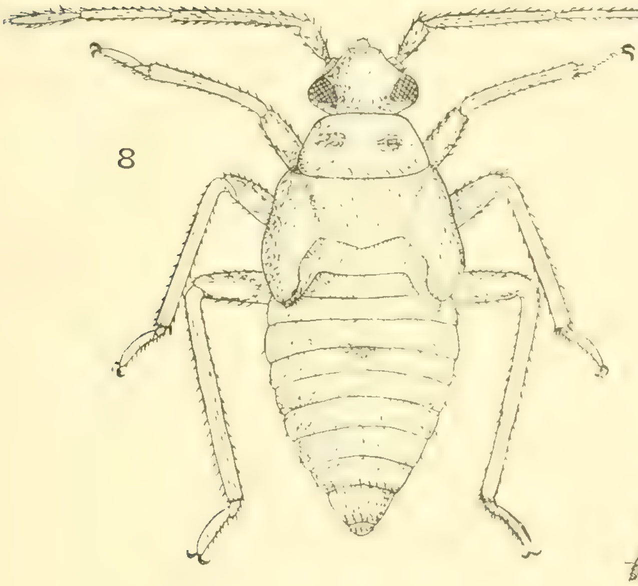

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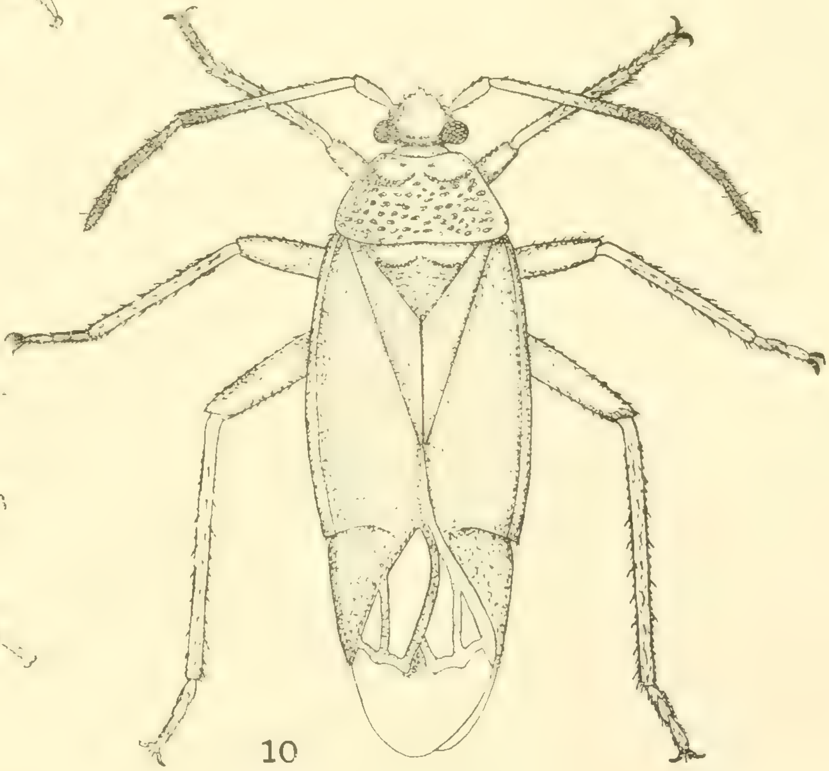

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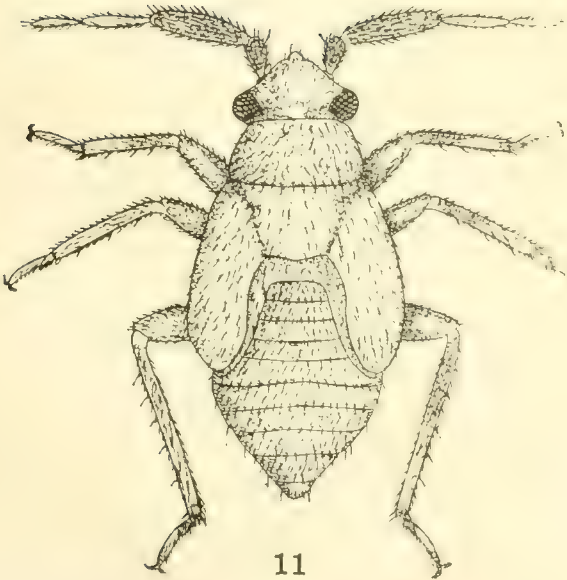

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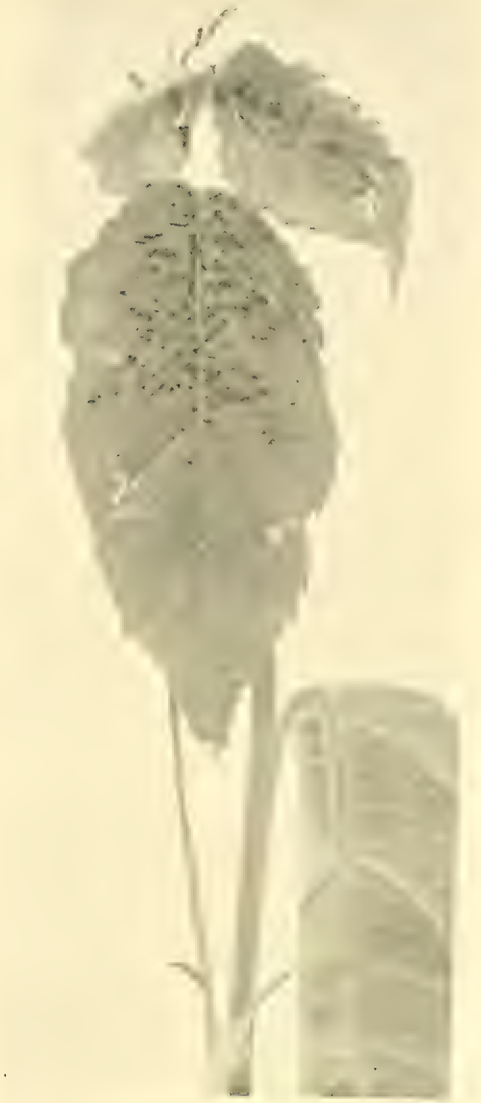

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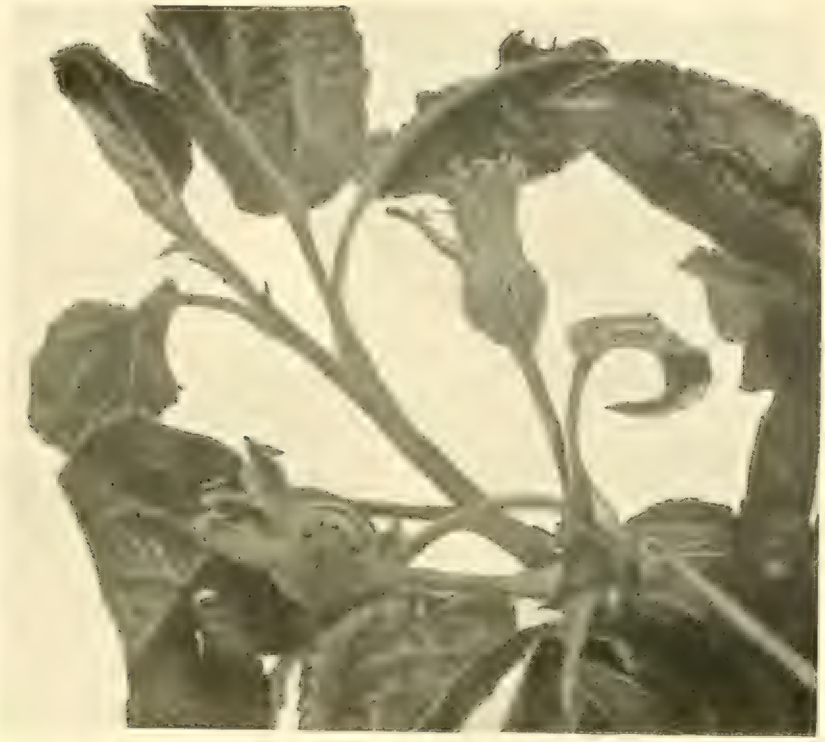

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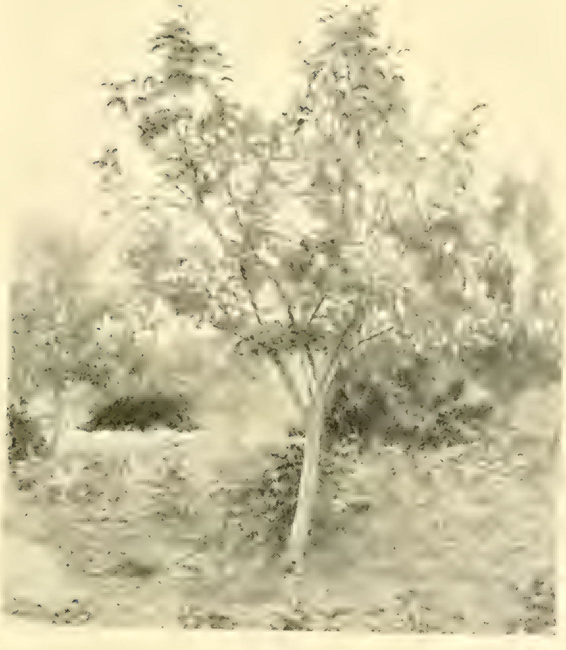

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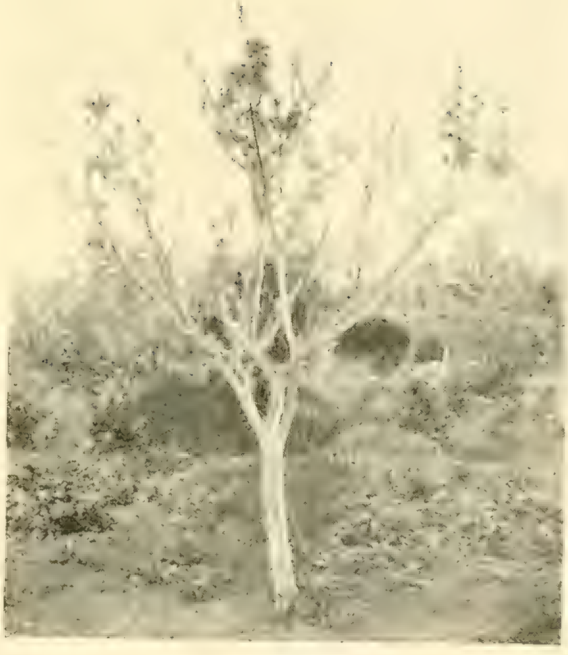

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EXPLANATION OF PLATES.

PLATE IX.

Fig. 1. Egg of *Plesiocoris rugicollis* in situ.
Fig. 2. Surface view of the cap of an egg of *Plesiocoris rugicollis* in situ.
Fig. 3. Eggs of *Plesiocoris rugicollis* in situ.
Fig. 4. A. Egg of *Plesiocoris rugicollis*.
B. Egg of *Orthotylus marginalis*.
Fig. 5. *Plesiocoris rugicollis*, Instar I.
Fig. 6. „ „ „ II.

PLATE X.

Fig. 7. *Plesiocoris rugicollis*, Instar III.
Fig. 8. „ „ „ IV.
Fig. 9. „ „ „ V.
Fig. 10. „ „ Adult.
Fig. 11. *Atractotomus mali*, Instar V.

PLATE XI.

Fig. 12. Apple leaves marked by *Plesiocoris rugicollis*.
Fig. 13. Young apples marked by *Plesiocoris rugicollis*.
Fig. 14. Two apple trees (variety Grenadier).
A. Sprayed and showing normal growth.
B. Unsprayed and showing a severe check to the growth of the leaves due to *Plesiocoris rugicollis*.

NOTES ON THE STRAWBERRY LEAF BEETLE (*GALERUCELLA TENELLA* LINN.).

By H. C. EFFLATOUN, F.E.S., M.R.A.C.

(With 3 Text-figures.)

Specimens of the larvae of this strawberry beetle, received by Mr F. V. Theobald were given to me to describe and follow out the life-history. The following are some notes I have made in regard to the various stages. It is hoped that, later, fuller details of the bionomics of this insect will be ready for publication. The insects bred in the laboratory of the South Eastern Agricultural College were sent to Prof. Theobald from County Monaghan, Ireland, where they had done much damage.

LARVA.

Length, one-eighth to one-sixth inch. Colour, dirty greenish yellow, head black. All the segments of the body, with the exception of the head, pronotum and anal segment, have a pair of elongate, transverse, thickish stripes, the cephalad stripe being larger than the caudad one. The stripes on the meso- and metanota are separated as shown in the figure. The dorsal segments are transversely furrowed. Each segment of the body, with the exception of the thoracic region (pro-, meso- and metanota) have four shining black tubercles on each side. These tubercles vary in size, the largest being near the transverse stripes. The pronotum is free from markings or tubercles and is uniformly dark brownish-grey. The meso- and metanota have two tubercles instead of four on each side; the inner pair are somewhat round, while the outer pair are much larger and somewhat crescent-shaped. The terminal segment is brownish-grey and more hairy than the rest of the body. There are three pairs of true (segmented) legs, which are black, on the three first segments of the body. Each bears two sharp claws. The anal segment possesses a large and simple process or proleg by means of which the larva progresses after the manner of one of the Geometridae. The body is covered with more or less numerous yellow hairs.

PUPA.

About one-tenth inch in length: dark yellowish-brown and slightly hairy. There are fourteen black spines on the dorsum of the cephalic region, each spine arising from a dark papilla, and eight smaller spines on the thoracic region.

The abdominal region has seven distinct segments, the first six of which carry a pair of large, black and shiny tubercles, a pair of small spines in the centre, and another pair of slightly larger spines on the sides. The lateral spines on the sixth segment are stouter and larger than the others. The antennae, instead of curling down between the legs, on the ventral side, extend outwardly and are curved round the back of the legs.

IMAGO.

Length, one-ninth to one-seventh inch. The colour varies slightly from dull yellow to pale brownish. The head has a broad black stripe across it and the head itself is yellow. The third joint of the antennae is longer in proportion than the second. The thorax has a small, more or less round depression on each side and is yellowish in colour with a dark furrow in the centre. The tubercles on the forehead are distinct and shiny. The punctures of the elytra are not deep but present a granulated and shiny appearance. The suture and margin of the elytra are yellow and the shoulders are dark. The ♂ has the fifth segment (ventral) of the abdomen slightly impressed at the apex, the same segment being almost entire in the ♀. The legs are pale; the antennae yellowish and dark at the apex. "The series in the British Museum shows some variation with regard to markings" (1) and "occasionally the elytra are marked with a more or less dark band" (2).

NATURE OF DAMAGE.

Both the larva and the imago damage the leaves of strawberries in exactly the same way. They eat the lower and upper epidermis and the soft underlying tissue, leaving the opposite layer of epidermis intact. The leaves then present a curious and characteristic spotted appearance. If the leaves are left exposed to weathering conditions they may then present a different appearance; they will appear as if regular holes had been eaten out of them and thus errors may arise when trying to identify the insect related to the damage.

The larvae from which the adults were bred were fully mature so that no observations were made as regards their habits, moults, etc.; pupation began the day following their arrival and this took place underground without the formation of a cocoon.

Date of pupation: June 21st–24th.

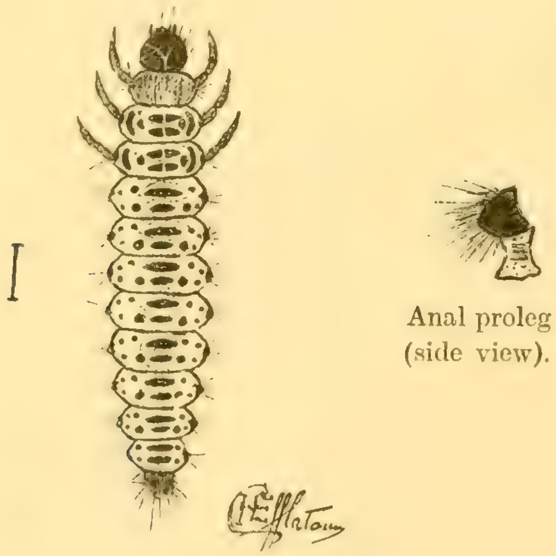
Adults hatched: July 22nd to 26th.

The beetles, on hatching, were in a fairly active condition but it took them from three to six days to harden. At the least sound or noise the beetles feigned death and dropped to the ground where they soon burrowed and disappeared out of sight. They were hardly ever observed to feed in the daytime. They fed mostly during the nights and early mornings, when quite a few did not seem to be disturbed, either by noise or even by handling their pot-plant.

This is not the first time that the species has been reported as injurious to the strawberry plant. Ormerod (3) received information of damage done by it from Hundred Acres, Wickham, Hampshire, with a note that they were destroying the strawberry plants in that neighbourhood, and that it was considered a new pest in the locality. Mr Theobald has received it this year from Buckinghamshire also.

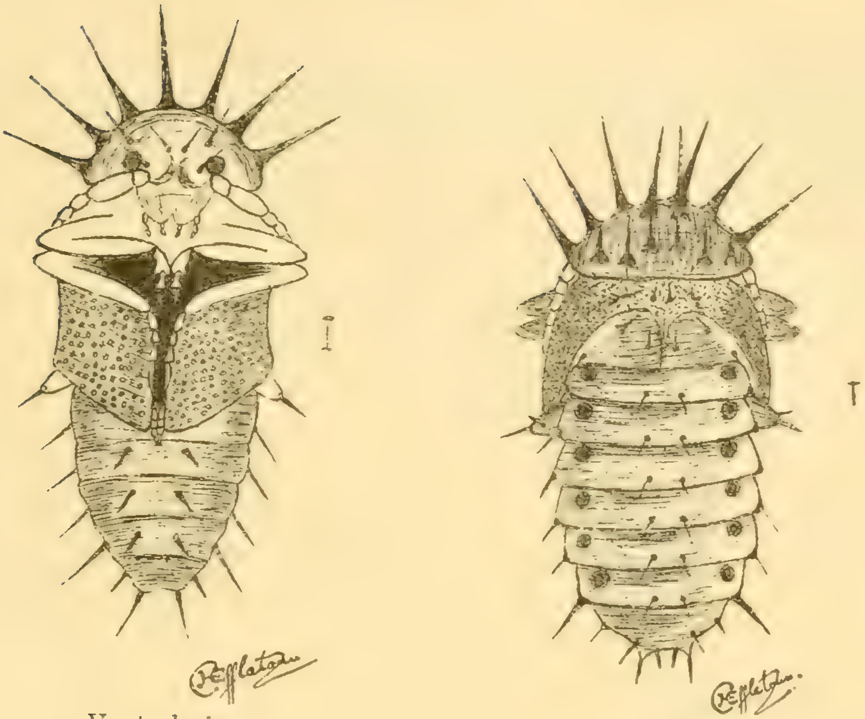
Lampa (4) records it from Sweden.

Sacharov (5) records it for the first time in Russia as injurious to strawberries. "The beetle winters," he says, "underneath old leaves on the beds of strawberries; with the arrival of warm weather the insects appear and feed on the young leaves, and oviposit during April and May. The eggs are deposited by the female in a hole gnawed by it in the leaf, 3–10 eggs being laid in such a hole. The egg-stage lasts 12–14 days."



Anal proleg (side view).

Fig. 1. Larva of *G. tenella*.



Ventral view. Dorsal view.

Fig. 2. Pupa of *G. tenella* Linn.

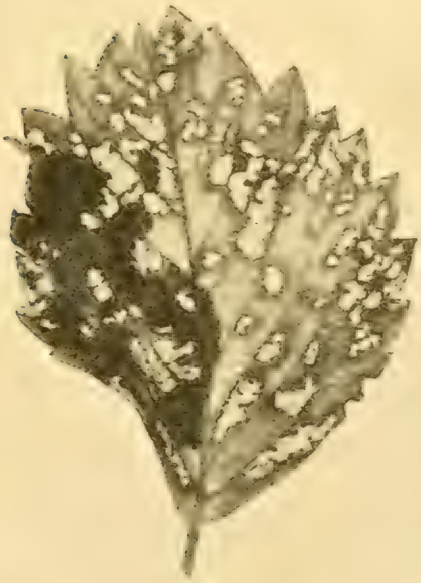


Fig. 3. Upper surface of leaf damaged by *G. tenella.*

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SOUTH EASTERN AGRICULTURAL COLLEGE,
WYE, KENT.
October 1*st*, 1917.

OBSERVATIONS ON *PIMPLA POMORUM* RATZ., A PARASITE OF THE APPLE BLOSSOM WEEVIL (INCLUDING A DESCRIPTION OF THE MALE BY CLAUDE MORLEY, F.Z.S.).

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(With Plate XII and 5 Text-figures.)

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1. INTRODUCTORY REMARKS.

Towards the end of May, 1916, I received several consignments of apple blossom buds attacked by *Anthonomus pomorum*. These were kindly sent at my request by Mr J. C. F. Fryer, Entomologist to the Board of Agriculture, who obtained them from an orchard at Chatteris, Cambridgeshire, where the weevil is often abundant. It is a well-known fact that *A. pomorum* is a most difficult pest to control on account of its concealed habits of feeding when in the larval stage, which greatly militates against the effective application of insecticides. The female weevil deposits her eggs in the blossom buds of the apple before they open, and, according to Theobald (1909, p. 106), the young larvae hatch out in from 5–7 days. The blossoms commence to expand but rarely fully open, further growth ceases, and the brown shrivelled petals form a kind of dome-like cap over the receptacle. If one of these so-called "capped blossoms" be opened the small white apodous larva of the weevil will be found in the centre. In many cases the larva of the weevil will be found to be dead, or weakly, and accompanied by a smaller larva not very unlike it in appearance. This latter larva in most instances will prove to be that of *Pimpla pomorum,* which forms the subject of the present investigation.

During the past year I have carried out a preliminary investigation of the parasites which attack the apple blossom weevil, in the belief that a possible method of control might eventually be afforded by the utilization of these natural agencies. In this connection it is noteworthy that Marchal (1907, p. 15) quotes the experiments of Decaux who was impressed by the multitude of ichneumon flies, or Braconids, which came out of apple buds attacked by *A. pomorum.* Instead of immediately burning these buds as was usually done, Decaux preserved them in boxes covered with gauze, raising the latter from time to time to allow of the escape of the parasites. In 1880 he put this method into use and collected in Picardy five hectolitres of buds from 800 apple trees. By this means, it is stated, that more than a million Anthonomi were destroyed and about 250,000 parasites liberated which, in the following year, were valuable aids in the destruction of the weevils. The orchards treated were surrounded by cultivated fields and consequently isolated from neighbouring fruit plantations. It sufficed to repeat the same operation during the following year, in order to prevent serious damage from the weevil during the succeeding ten years, so thoroughly had the parasites done their work.

The results obtained during one year's preliminary investigation confirmed my surmise that the apple blossom weevil is, in certain localities, at any rate, in this country, equally heavily parasitised. Owing to the great difficulties in obtaining labour entailed by the War, it has not been found possible to prosecute these investigations any further at present, as very considerable quantities of affected blossoms are needed from various parts of the country. Nevertheless, the facts already observed are, I think, of sufficient importance to merit publication. I must express my indebtedness to Mr Claude Morley, who examined a pair of the adult ichneumons submitted to him and identified them as belonging to the species *Pimpla pomorum* Ratz.

2. THE FEMALE.

This species was first described by Ratzeberg (1848, p. 96) from females bred by Reissig from *Anthonomus pomorum* in pear blossom which is an infrequent host plant for the latter. Subsequently both sexes were reared from the same weevil by Nordlinger, and Ratzeberg later adds (1852, p. 103) that Reissig bred both sexes from apple blossom. In 1912, Catoni recorded having reared considerable numbers in the Trentino.

As adequate descriptions of this sex are given by Schmiedenknecht (1906, p. 1084) and Morley (*loc. cit.* p. 76), it is neither desirable nor necessary to add anything further so far as the female is concerned.

Morley states that examples of this sex are one of the commonest of all Ichneumonidae in Britain in the early spring. There are, however, very few records apparently due to the fact that the insect was not recognised as being a British insect until 1889 when Bridgman established its identity. Up to the present, it is known from certain of the southern and south-eastern counties, but further collecting and observation will doubtlessly reveal its distribution to be more widely spread.

3. THE MALE.

Although the female is an abundant insect very little has been known concerning the male. Ratzeberg surmised that an example bred by Nordlinger, along with females of this species, probably belonged to it; similar males and females were afterwards reared by Reissig. In 1912 Catoni reared a number of males from the *Anthonomus* in Italy but apparently was unaware of their seeming rarity. I know of no further records concerning this sex. Ratzeberg's description is very brief and inadequate but, since it was the only information available, is copied by Schmiedenknecht (1906, p. 1085) and Morley (1908, p. 77). During the course of the present investigation I have bred out a considerable number of examples of this sex and as the result I am able to include herewith a full description thereof which has been drawn up and forwarded to me by Mr Claude Morley.

DESCRIPTION OF THE MALE OF *PIMPLA* (*EPIURUS*) *POMORUM* RATZ., BY CLAUDE MORLEY, F.Z.S., ETC.

Head with the face and short cheeks immaculate black; mandibles and palpi pure white. Antennae filiform and not apically attenuate, nigrescent testaceous and about half the length of body, pale beneath with the scape and pedicellus pure white below. Thorax with short white humeral callosities before radices, but the collar not in this instance (as is stated by Ratzeberg) pale; metanotal areae wanting, at most the basal indicated; metathoracic apex impressed before a longitudinal carina on either side; spiracles circular. Abdomen linear and not very strongly punctate; basal segment distinctly punctate laterally; third segment distinctly a little longer than broad (as in *P. ulicicida,* Morl.; *Entom.* 1911, p. 161, ♂ ♀ and herein my character for their distinction given at *Revis. Ichn. Brit. Mus.* III. 1914, p. 82, fails in the ♂ sex); the deeply impressed thyridii, and the third to fifth segments especially basally, pale castaneous; the sixth to eighth narrowly whitish apically; valvulae inconspicuous. Anterior legs and hind trochanters white, with onyches and onychii of the intermediate tarsi nigrescent: front femora entire and not emarginate beneath; hind coxae and femora pale testaceous; hind tibiae white, with apical third and a band before base connected by an internal striga nigrescent; pulvilli large, but shorter than claws; calcaria and basal third of metatarsus white. Wings with the radix and tegulae white, stigma pale luteous; basal nervure continuous through median; areolet nearly twice as broad as long, emitting the oblique second recurrent nervure from very near its apex; nervelet obsolete; nervellus hardly geniculate and intercepted by the weak spurious nervure at its lower third or fourth.

This male has hitherto been mixed in Britain with that of *P. punctiventris* Thoms. which name is inserted *in errore* at *Ichn. Brit.* III. 1908, p. 81.

In the above description Morley describes the scape and pedicellus of the antennae as being pure white below. From an examination of eight examples these joints were seen to be stramineous in every case, so possibly there is some variation in this respect. As the sexual differences are very marked in this species I append below an enumeration of the most characteristic features afforded by a comparison of a number of male and female examples.

MALE	FEMALE
Scape of antennae stramineous ventrally	Scape of antennae fuscous ventrally
Thorax black	Mesothorax, the greater part of the pleurae, and a pair of apical spots on the mesothorax, red
Abdomen minutely punctate, testaceous or infuscate	Abdomen coarsely punctate, dark brown or almost piceous
First abdominal segment oblong	First abdominal segment not longer than apically broad

4. OBSERVATIONS ON THE BIOLOGY OF THE SPECIES.

The larva of this Ichneumon lives entirely external to its host, which may be either in the larval or pupal stage of development. Whether it is the larva or pupa that is destined to furnish the food-supply of the

Pimpla, depends upon the time of oviposition by the latter. The earliest hatched larvae meet with larval weevils only, but the later examples will, more often than not, find the host in the pupal condition. Whichever occurs the life of the parasite is the same. Its young larva is usually to be found on the dorsal side of the host larva, with the mouth-parts immersed within the tissues of the latter. The position occupied by the parasite is not constant since the latter was found attached to its host in the following situations: to the fourth tergum; between the eleventh and twelfth terga; to the eighth tergum; between the third and fourth terga; to the second tergum; to the sixth tergum and, in one instance, between the twelfth and thirteenth sterna.

If it be the pupa that is attacked, the parasite was invariably observed to select the anal extremity of the latter. Half-devoured pupae were often met with, the abdomen being largely shrunken away, though the remaining portion of the host appeared to be quite fresh, and exhibited no signs of discoloration or putrefaction. Under these circumstances, it appears not unlikely that the parasitic larva may inject some kind of secretion into the tissues of its host, serving as an antiseptic arresting decomposition.

Only a single parasite was found in relation to each individual host, and a good deal of overlapping of the development stages was found to occur—a feature which is far from rare among hymenopterous parasites. Thus, on May 25th, I found *Pimpla* larvae 2 mm. long, half and fully grown larvae, larvae commencing to spin their cocoons, and fully formed pupae from among less than fifty examples of the *Anthonomus*.

When fully fed, the larva spinsa slight silken cocoon, which is ovoid in shape, measuring on an average 6 mm. long and 2 mm. in diameter (Text-fig. 5). The cocoon can be readily detected within the cavity of the affected apple bud; the silk of which it is composed is white, or, in some instances, the outer fibres thereof are pale brown in colour. When examined under a low power objective, the fibres can be readily observed to be arranged for the most part in a circular manner around girth of the cocoon. The whole structure, and the interstices between the threads, is varnished over with a very thin and transparent layer of glutinous secretion.

Under laboratory conditions, the first example issued on June 17th, 1916, and was a male, the actual time being twenty-three days from the date of commencement of spinning the cocoon. From the above date onwards, until July 5th, a large number of the parasites emerged, the first female appearing on June 21st.

It is noteworthy that all of some eighty unparasitised examples of the host weevil, reared during this investigation, emerged from the pupa prior to the appearance of the *Pimpla*, none issuing later than June 13th.

After the emergence of the perfect insects, the subsequent life of the species is a mystery. It is perfectly clear that there is no available supply of the larvae or pupae of the weevil until the following year. It appears improbable that the adult parasite awaits a period of about ten months for the reappearance of its larval host. Most probably it utilises an alternative species, and passes through a second annual generation, though what that host is likely to be is hard to predict.

A further point of interest is the fact that the parasite occurs in districts where *Anthonomus pomorum* is unknown. For example in Suffolk, according to Morley (1908, p. 77), this weevil is absent, nevertheless the parasite is a common insect in that county, and may be frequently beaten out of Coniferae. Nothing, however, is known regarding the host which it utilises on such occasions.

In this connection some clue may possibly be afforded if we take into account the various hosts utilised by other species of the genus *Pimpla*. There is no doubt whatever that Lepidoptera are usually selected and, out of the forty British species of *Pimpla*, which are enumerated by Morley (1908, pp. 51–118), the vast majority have been bred from various members of this order of insects. The most usually parasitised species are *Retinia buoliana*, *R. resinana*, *Tortrix viridana*, *Orgyia antiqua*, *Odonestis potatoria* and *Clisiocampa neustria*. Many other species, however, serve as hosts and great variation is exhibited in the size of the host selected. Thus *Pimpla rufata* Gmeb. has been bred from *Tortrix viridana* and the relatively gigantic *Sphinx ligustri*; and *P. instigator* Fab. from *Psyche viciella* and *Smerinthus populi*! Outside the order Lepidoptera there are few reliable records; four British species of *Pimpla* have been bred from the egg masses of spiders and about six species have been reared from Coleoptera, almost exclusively Curculionidae. With the exception of *Pimpla pomorum* these latter species have been reared from Lepidopterous hosts also. Of the species known to parasitise *Anthonomus pomorum* the following host records are enumerated by Morley (1908, pp. 60, 81, and 99). *Pimpla graminellae* has been reared from *Odonestis potatoria*, *Epippiphora scutulana* (or *E. pflugiana*) and *Clostera reclusa*. *Pimpla sagax* has been reared from *Retinia buoliana*, *R. resinana*, *R. turionana*, *Coccyx cosmophorana*, *Tischeria complanella*, *Conchylis posterana*, and *Lithocolletis trifasciella*. Morley (*loc. cit.* p. 81) also records an example bred on April 26th from dried heads of *Centaurea nigra* gathered beneath fir trees. He suggests the gall-forming Trypetid *Urophora solstitialis* as its host, "unless of course its presence there was purely accidental and its true association were with the overhanging conifers, in which case it would surely have shown itself in the jar in the course of the preceding month." In my opinion it is more probable that one or other of the several species of Lepidopterous larvae which inhabit the flower heads of *Centaurea* is the host in question. *Pimpla examinator* Fab. has been bred from *Retinia buoliana, Liparis chrysorrhoea,* and many other Lepidoptera. *Pimpla pomorum* is exceptional in that it has only been bred with certainty from *Anthonomus pomorum.* From analogy with other species of its genus it is probable that it utilises Lepidopterous hosts also, although it is remarkable that it has not so far been reared therefrom. Morley states that he has invariably beaten it from *Pinus sylvestris* and *Picea excelsa* in fir woods about Bentley in Suffolk. This suggests that *Retinia buoliana* or other pine infesting Tortricid may prove to be one of its hosts. In the absence of pine trees (as in the Chatteris locality, Cambridgeshire) certain of the commoner Lepidopterous larvae feeding on apple, hawthorn and other plants, may not unlikely prove to be parasitised by this species.

As a general rule the parasites of exposed hosts—in other words host insects not sheltered by a cocoon, or in a bud, leaf or stem—live internally. Howard has remarked (1913, p. 161) that it is very rare to find an external Hymenopterous parasite on an unprotected host insect, and it occasionally happens that the same species of parasite, in its larval stage, will feed exteriorly upon a protected host and interiorly upon an unprotected host. So little is known concerning the biology of the genus *Pimpla* that it is impossible to assert how far the ecto- and endoparasitic habits prevail, as both protected and exposed hosts may be utilised by one and the same species. A thorough investigation of the economy of members of this genus is likely to yield results of considerable biological interest and importance.

5. THE YOUNG LARVA.

The smallest larva met with measured 1·1 mm. long (Plate XII, fig. 1) and, although I have had no opportunity of examining the newly hatched individual, I have little doubt that it does not differ from the latter in any essential details of its morphology. It is pearly white in colour, and differs from the fully grown larva in the following among other features. (1) The relatively large size of the head, which is completely exserted, and incapable of any withdrawal into the first trunk segment. It measures ·22 mm. long and ·24 mm. broad, the ratio of the length of the head to the total length of the larva being as 1 : 5·4; in the fully grown larva the ratio is 1 : 8·3. The antennae are equal in size to those of the fully grown larva, and are consequently of a much greater relative size. (2) The dorsal curvature of the body is much less pronounced. (3) The labial and maxillary papillae are represented in each case by a group of six or seven minute cuticular structures on either side (Text-fig. 1). (4) The body segments are more rounded and uniform in character, and the dorsal pseudopodia are not yet formed. (5) The tracheal system is incompletely developed, and nine pairs of spiracles are present, the minute vestigial second pair not yet being evident.

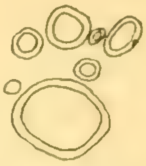

Fig. 1. Papillae from the left ventral side of the labium of a young larva: highly magnified.

6. THE FULLY GROWN LARVA.

When fully grown the larvae vary from whitish, or dull cream colour, to pale brownish white or pink, and measure when alive from 4·5 to 5 mm. in length, with an average maximum breadth of 1·25 to 1·5 mm. They are elongate fusiform in shape, narrowing towards the two extremities, and more so at the anal than at the cephalic end. The dorsal surface is more prominently arched than the ventral (Plate XII, fig. 2), and the cuticle is studded with numerous minute conical chitinous papillae. These structures have an average diameter of ·004 mm. and give the cuticle, under a low magnification, the appearance of fine shagreen; those on the dorsal region are slightly larger than elsewhere. A few short setae occur and, for the most part, are grouped in the form of a loose circlet around the middle of each segment. A well-defined head is present followed by thirteen sharply demarcated body segments, which are related to one another in length in the following proportions: 6–7 : 6 : 5–6 : 6 : 7 : 7–8 : 8–9 : 8–9 : 7–8 : 6–7 : 5 : 3–4 : 3. Owing to the variable amount of contraction or extension which the segments undergo, these ratios are not capable of more exact determination. The *head* differs from the remainder of the body in being enclosed in a smooth and slightly thicker chitinous investment; it is, moreover, usually a little darker in colour. It is about as broad as long, measuring ·6 mm. in either direction. On the dorsal aspect, it has two ovoid or somewhat pyriform infuscate markings, which are placed alongside the middle line, parallel with the longitudinal axis. Definite though vestigial *antennae* are present; they are peg-like in form and measure ·049 mm. long and ·007 mm. wide across the middle region (Text-fig. 2).

The *mandibles* (Text-fig. 3) closely resemble one another. At its base, each is flattened and plate-like and measures ·07 mm. in breadth; apically it is drawn out into a straight spine-like piercing tooth, beset with minute spines along a portion of its antero-posterior margins. The mandible measures, from the apex of the tooth to the condyle, ·11 mm. in length.

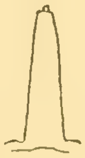

Fig. 2. Right antenna of a fully grown larva: highly magnified.

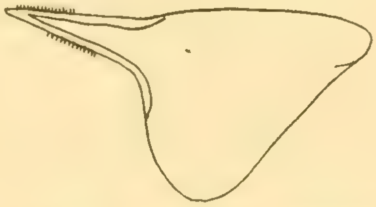

Fig. 3. Right mandible of a fully grown larva. ×300.

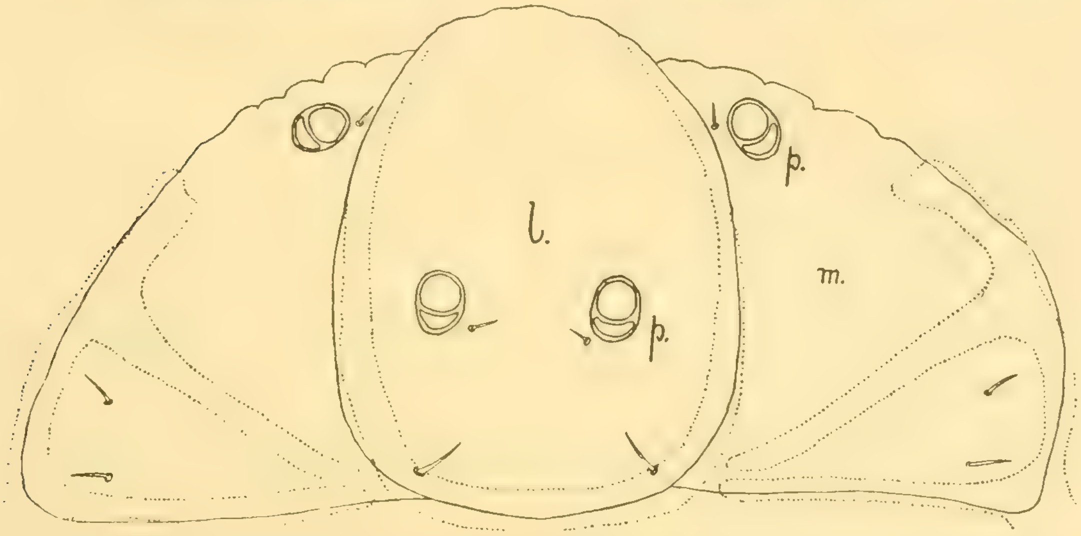

Fig. 4. Ventral view of the labium and 1st maxillae of a fully grown larva; ×600. *l*, labium: *m*, 1st maxilla (left): *p*, sensory (?) papillae. The dotted lines indicate the position of the underlying head skeleton.

The *mouth* is bounded dorsally by the labrum, laterally by the first maxillae, and its floor is formed by the labium. The *labrum* is an oblong transverse plate, slightly curved and measures ·13 mm. from side to side, and ·04 mm. in the antero-posterior direction. The *first maxillae* (Text-fig. 4) are extremely simple and their ventro-lateral margins are closely applied to the sides of the labium. No traces of galeae or laciniae are to be found, neither is there any division into basal sclerites. Near to its outer free margin each maxilla carries a papilla (*p*) arising from a divided basal ring of chitin measuring ·015 × ·011 mm. This structure occupies the same position as the group of small papillae found in the young larvae. The *labium* (*l*) is ovoid in form and measures ·14 mm. in length and ·10 mm. broad (Text-fig. 4). Its free margin is simple and undivided; a pair of papillae (*p*), similar in form and size to those found in the first maxillae, are also present. These are similarly represented in the young larvae by a pair of groups each comprising seven minute papilla-like structures. From their position and constancy of occurrence, these structures suggest their possibly being the vestigial counterparts of the labial and maxillary palpi, and have been regarded as palpi by Cushman in his description of the larva of *Thesolochus conotracheli* (1916, p. 853 and Fig. 8). The fact that in *Pimpla pomorum*, at any rate, they are represented in the young larvae by groups of minute papillae, militates against this interpretation of their morphology.

The *trunk* segments are separated by deep, well-defined intersegmental grooves, and segments 4 to 10 have the tergal region raised in such a manner as to form a row of transverse mid-dorsal tubercles or pseudopods. These are only slightly developed and are more noticeable from a lateral rather than from a dorsal view (Plate XII, fig. 2). In a similar way, the lateral regions of the same segments are slightly produced outwards to form rounded mamilla-like swellings. Ten pairs of *spiracles* are present, and are situated on the first, second, and fourth to eleventh segments. The first pair is placed on the posterior region of its segment, near the intersegmental groove separating it from the succeeding segment. The second pair of spiracles is vestigial and non-functional. These spiracles are very small and hard to detect; they occupy a position on their segment similar to that of the preceding pair. No spiracles are present on the third segment, while the remaining eight pairs are situated far forwards on their respective segments.

7. COMPARISON WITH LARVAE OF OTHER ICHNEUMONOIDEA.

In the possession of a well-defined head and thirteen body segments the larva of *Pimpla pomorum* conforms to the usual type found among Ichneumonoid larvae. This same number of segments has been found to obtain in a number of species, notably by Xambeu (1898)[1] in *Pimpla oculatoria* Grav., by Seurat (1899) in *P. mexicana*, by Giraud (1863) in *P. detrita* Holmg. (*graminellae* Grav.), by Ratzeberg (1844) in *Exochilium* (*Anomalon*) *circumflexum* L., by Riley (1888) in *Thalessa lunator* Fab., by Berthoumieu (1894) in *Ichneumon rubens* Fons., by Morley (1903) in

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[1] Xambeu mentions (p. 239) twelve segments in *P. oculatoria*, the hindmost being "prolongé par un mamelon rétractile"; the latter structure, however, appears to be the reduced thirteenth segment.

Exetastes cinctipes Retz., by Wardle (1914) in *Hypamblys albopictus* Grav., by Cushman (1916) in *Thersolochus conotracheli* Riley, by Klapálek (1889) in the curious larva of *Agriotypus*, by Cushman (1913), and subsequently by Smith (1914) in *Calliephialtes*, and also by Seurat (*loc. cit.*) in the following species: *Mesochorus vittator* Zett., *Anilasta ebenina* Grav. et Thom., *Xylonomus praecatorius* Fab., and *Phymatodes variabile*. Newport (1855) similarly recognised thirteen segments in the larvae of *Paniscus virgatus* Fourc., and *Anthophorabia* (*Mellitobia*) *retusa* Newp., while Graf (1917) figures a similar number in the larva of *Bassus gibbosus* Say. Apparent exceptions to this rule are often difficult to explain, and very possibly in some instances the small thirteenth segment has been overlooked. Thus Timberlake (1912) only recognised twelve segments in the larva of *Limnerium validum* (Cress.) and Morley (1914) mentions a similar number in *Paniscus cephalotes* Holmgr. In *Ichneumon atropos* Curt. Newport (*loc. cit.*) detected fourteen segments, including the anal process, but the latter structure is most probably an outgrowth of the thirteenth segment and this species would therefore conform in possessing the usual number of segments. In *Spilocryptus cimbicis* Tschek. Morley (1907) states there are twelve segments, apparently including the head in his enumeration; in the onisciform larva of *Mesostenus obnoxius* Grav. this same observer (1906) found only nine segments.

In the retention of ten pairs of spiracles the larva of *Pimpla pomorum* exhibits a primitive feature not hitherto recorded, so far as I am aware, in any other species of Ichneumonoidea. Laboulbène (1858) noticed nine pairs of spiracles in the larva of *Pimpla Fairmairii* and the same number has been observed by Giraud in *P. detrita* Holmgr., by Xambeu in *P. oculatoria* Grav., by Ratzeberg (1844) in *Ichneumon pisorius* L., by Berthoumieu in *I. rubens* Fons., and by Seurat in *Pimpla mexicana*, *Anilasta ebenina*, *Xylonomus praecatorius*, *Mesochorus vittator*, and *Phymatodes variabile*. The vestigial second pair of spiracles is very small, being easily passed over, and it is not improbable that, in certain cases, it has been overlooked by previous observers. It is noteworthy that ten pairs of spiracles are also present in the newly hatched larva of the honey bee, but in this species they correspond, according to Nelson (1915), to the second to eleventh segments inclusive.

In the presence of body hairs, and the absence of either a caudate appendage or anal vesicle, the larva of *Pimpla pomorum* exhibits features that are characteristic of Ichneumons leading an ectoparasitic mode of life.

8. THE MALE PUPA.

In describing the pupa, whether male or female, one meets with the very real difficulty of selecting from the few characters which it affords, those which appear to be of diagnostic value. In hardly a single instance do we find a description of an Ichneumonid pupa sufficiently detailed to be of value for comparative purposes. So far as the present species is concerned, I have only dealt with those morphological features which appear likely to prove of generic or specific value. Of these, the characters afforded by the abdominal spines appear to be important.

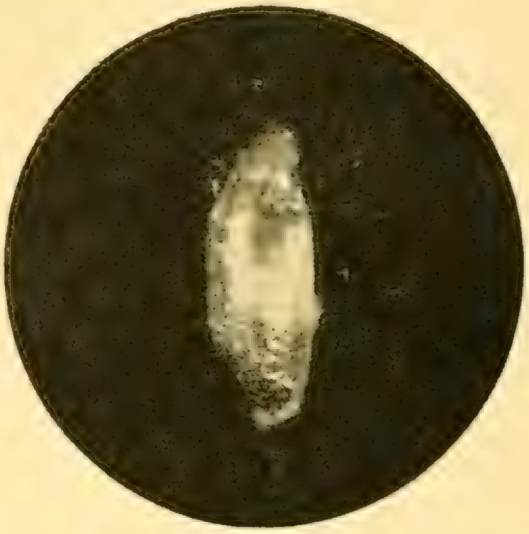

Fig. 5. Cocoon showing the emergence hole made by the adult Ichneumon. × *circa* 5.

In the *male pupa* (Plate XII, fig. 3) the head is a little wider than the thorax across the widest region, with the frontal surface inclined obliquely downwards. The mouth-parts are wholly ventral in position, with the first maxillae and labium lying parallel with the longitudinal axis of the body, and near to the surface of the prosternal region. The antennae curve over the anterior surface of the head, closely applied to the inner margins of the eyes, and lie for the remainder of their length on the ventral side of the body. Their apices extend backwards as far as the fourth abdominal segment. The extremities of the anterior tarsi reach as far as the apices of the middle tibiae; the second pair of legs are wholly invisible dorsally and their extremities reach to the middle of the second tarsal joint of the hind legs; in the third pair of legs the apices of the tarsi extend slightly further backwards than those of the antennae. The fore-wings completely overlie the hind-wings and exclude them from view; they reach backwards as far as the extremity of the first tarsal joint of the middle legs. Seven segments are evident in the abdomen but the seventh or hindmost segment is of a composite nature and apparently consists of two partially fused pupal segments. The first segment is devoid of spines, while the second to fourth segments are each armed with a single pair of small ventral spines. The fifth segment is provided with four ventral and two dorsal spines; the sixth segment has a circlet of spines of which usually six are ventral in position, four are lateral and four dorsal. The apical region of the abdomen is prolonged posteriorly into a pair of short appendages, which are imperfectly two-jointed, and rounded at their extremities. On either side of these appendages, is a pair of papillae, each carrying a conspicuous curved spine, considerably longer than the spines on any of the preceding segments; a pair of smaller spines are also present ventrally.

Length 5 mm.; maximum breadth across the thorax 1·5 mm.

9. THE FEMALE PUPA.

The female pupa (Plate XII. fig. 4) differs from the male pupa in that the antennae extend as far backwards as the sixth abdominal segment while the hind legs reach to the seventh segment. The terebra is folded back over the dorsal side of the abdomen, its apex reaching to the middle of the first segment. The latter is unarmed, but the second and third segments are each provided with a pair of small dorsal spines. The fourth segment has four similar dorsal spines and two ventral spines; vestiges of a second and outer pair of ventral are also present. The fifth segment is armed with four dorsal, two ventral and two prominent lateral spines —one on either side. The sixth segment has usually six ventral, four dorsal and large lateral spines. The seventh or apical segment is provided, on either side, with a pair of large curved ventro-lateral spines as in the male, and, furthermore, is prolonged backwards in the form of a pair of unjointed appendages each surmounted by a conspicuous spine.

Length 4·25 mm. to 4·45 mm.; maximum breadth across the thorax 1·5 mm.

10. EFFICIENCY AS A PARASITE.

Between May 25th and 29th, 1916, 1270 apple buds, harbouring the weevil in various stages of development, were separately examined under a binocular microscope. Among these infested buds 349 contained larvae of *Pimpla pomorum.* This gives a ratio of parasitism working out at 27·4 per cent., which is a relatively high one, and remarkably near to that found by Decaux to be efficient in France in the control of the weevil by means of species of Braconidae. A further 605 buds gave inconclusive results, and are not included in this enumeration. Many of them were either attacked by mould or were empty, or contained dead or sickly hosts, without certain indications of being parasitised by the *Pimpla.* The appearances in many cases suggested that the parasite had been present, but had died along with the host. Mould favoured by wet weather, appeared often to kill the latter when parasitised, and the parasitic larva usually died also as the result. When the petals of the unopened buds were not tightly closed, the mould appeared to gain access more readily.

The effect of the parasitism on the host is complete, the latter dying in every instance whether it be in the larval or pupal stage. It is probable, therefore, that *Pimpla pomorum* is an important natural aid in the control of the apple blossom weevil in this country. The high rate of mortality which I have shown it exacts from its host, together with the general fact of its biology, clearly supports this contention. Measures involving the preservation and increase of the parasite, along lines similar to those conducted in France, are fully worthy of adequate trial as an accessory means of controlling the weevil. The utilisation of natural enemies in the control of injurious insects has led to highly encouraging results in America, Italy, France and elsewhere; nevertheless, it is a method which can only be advocated after a thorough scientific enquiry into the life-economy of each particular species and its parasites. In the case of the apple blossom weevil, among the various measures recommended for dealing with this insect is that of jarring the trees, which causes the affected apple blossoms to fall readily. Frequently, many fall in the natural course of events without the trees being shaken. The blossoms are then collected and burnt. With the expenditure of very little extra time and labour the blossoms, after being collected, might easily be placed in boxes and saved. Shallow well-fitting wooden boxes are best for the purpose, and not more than six layers of blossoms should be placed in a single box, as they rapidly decompose and rot in damp weather. The lids of the boxes should have as large an area as possible replaced by cheese cloth or butter muslin, to allow of the admission of air and light. If, however, the finest holed perforated zinc be used the boxes will then serve their purpose for a much longer period without trouble. All that is necessary is to examine the boxes daily from about the beginning of the second week in June, removing the lids thereof for a few minutes to enable the parasites to fly away once they commence appearing. It is advisable to jar the box sharply before doing so, in order to cause those weevils which may have crawled up the sides to loose their foothold and so prevent their escape. By this means the greater number of the weevils are imprisoned within the boxes and eventually die, while the parasites are liberated to continue their beneficial mission. Experiments were conducted in order to ascertain whether it be possible to utilise gauze of such a mesh which would allow of the liberation of the parasites, and the retention of the beetles, and thus obviate the necessity for the periodical removal of the lids of the boxes. Owing to the relatively large size of the parasites, compared with the size of the host, it was found that the parasites did not readily issue through a mesh which, at the same time, was small enough to imprison the host weevils. The method of collecting the affected blossoms followed by the burning of the same, is open to a good deal of doubt as to its advisability on account of the large number of beneficial parasites which are destroyed at the same time.

11. REMARKS ON OTHER PARASITES OF *ANTHONOMUS POMORUM*.

A useful summary of hymenopterous parasites recorded from this host is given by Elliott and Morley (1907 and 1911) and further records are quoted by Catoni (1912). Several of the statements, however, are of doubtful value as they probably refer to parasites of Aphids and other insects and have no closer connection with *Anthonomus* than the fact that the host food-plant was apple in each case. Among these doubtful records may be included *Apanteles* (*Microgaster*) *albipennis* Nees, *Bracon variator* Nees, *Asaphes vulgaris* Walk. (*Chrysolampus aeneus* Ratz.), *Encyrtus flavomaculatus* Ratz. and *Pteromalus* (*Habrocytus*) *saxesenii* Ratz. (Thoms.). Brischke, however, has bred *Pimpla examinator* Fab., *P. sagax* Htg., and *Apanteles* (*Microgaster*) *lacteus* Nees from this host. *Apanteles* (*Microgaster*) *impurus* Nees was frequently bred by Reissig from apple blossom infested by the weevil and has also been reared by Catoni. According to Ratzeberg (1848, p. 84), Nordlinger bred a single male of *Campoplex latus* Ratz., and it is stated that Goureau has bred *Pimpla graminellae* Grav. from the same host. Catoni (1912, p. 149) has also bred *Meteorus ictericus* (Nees) and *Habrocytus fasciatus* Thoms.

During this investigation *Pimpla pomorum* was the only parasite which I bred from the *Anthonomus*. Whether or not any of the above species are likely to prove of value from the economic point of view is doubtful. Males of *Pimpla examinator* are common in this country though no certain records of the female appear to be known. *P. sagax* has not often been met with while, according to Morley, there are but few reliable records of *P. graminellae*.

The species of *Apanteles* are well-known natural enemies of Lepidoptera and the extent to which they may parasitise insects of other orders requires fuller investigation before we are able to formulate definite conclusions with regard to their economic significance.

12. SUMMARY OF GENERAL CONCLUSIONS.

1. *Pimpla pomorum* Ratz., in its larval stage, is an ecto-parasite of the Apple Blossom Weevil (*Anthonomus pomorum*) attacking both larvae and pupae of the latter.

2. The larva of this Ichneumon is composed of a definite head and thirteen trunk segments; no caudal process or anal vesicle is present. Ten pairs of spiracles are evident but the pair situated on the second segment is minute and vestigial.

3. Pupation takes place within a slight silken cocoon spun within the cavity of the unopened apple buds. The adult Ichneumons commenced to emerge on June 17th, and an average of twenty-three days was occupied from the time of spinning the cocoon.

4. The male insect was met with in considerable numbers for the first time, and its identity made certain. Hitherto nothing has been known of this sex beyond Ratzeberg's surmise that a male *Pimpla* bred by Nordlinger belongs to this species and that Catoni has reared it in Italy. A full description of the male by Mr Claude Morley is included in the present paper.

5. After emergence in June, the biology of this species during the rest of the year is unknown. Most probably it passes through a second generation and utilises certain species of Lepidoptera as hosts. In localities where *Anthonomus pomorum* is unknown both generations probably parasitise Lepidoptera.

6. From among 1270 apple buds gathered at Chatteris in Cambridgeshire, and infested by the Apple Blossom Weevil, *Pimpla pomorum* was found to effectively parasitise the latter to the extent of 27 per cent. This ratio of parasitism is relatively high, and agrees very closely with that found by Decaux to obtain among Braconid parasites of the same host.

7. It is suggested that measures involving the preservation and increase of this parasite, along lines similar to those conducted in France, should be given an adequate trial; it is likely that they may prove of value as an accessory means of controlling the weevil.

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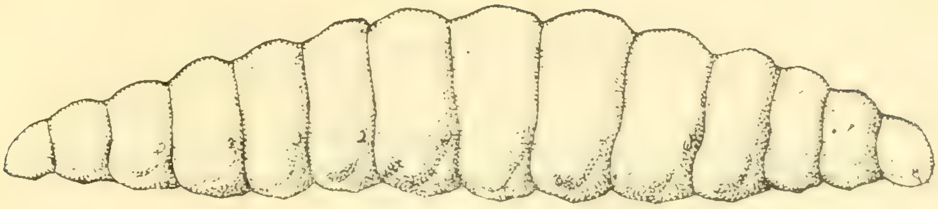

Fig. 1

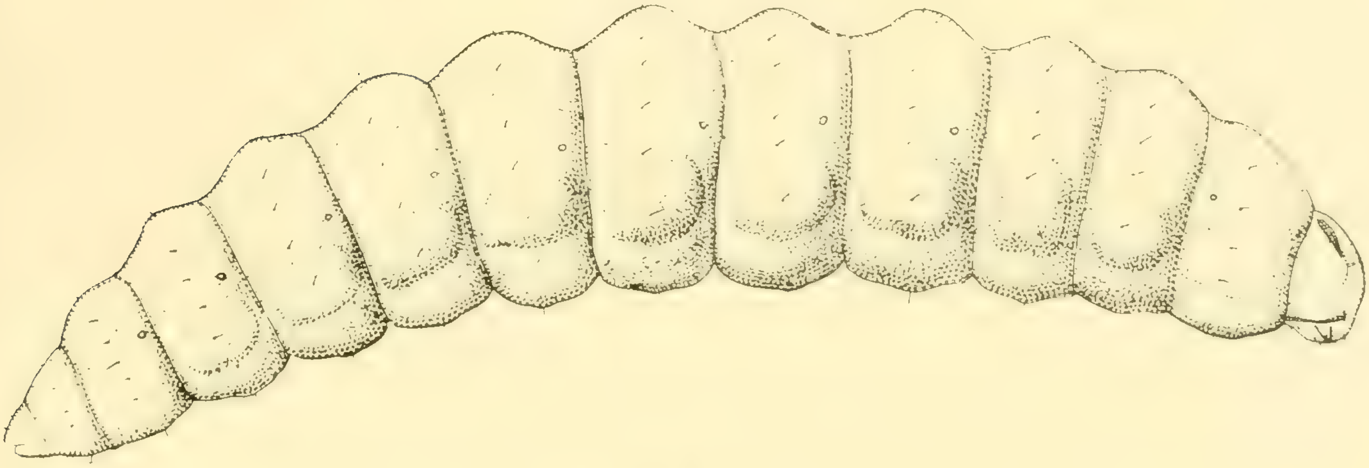

Fig. 2

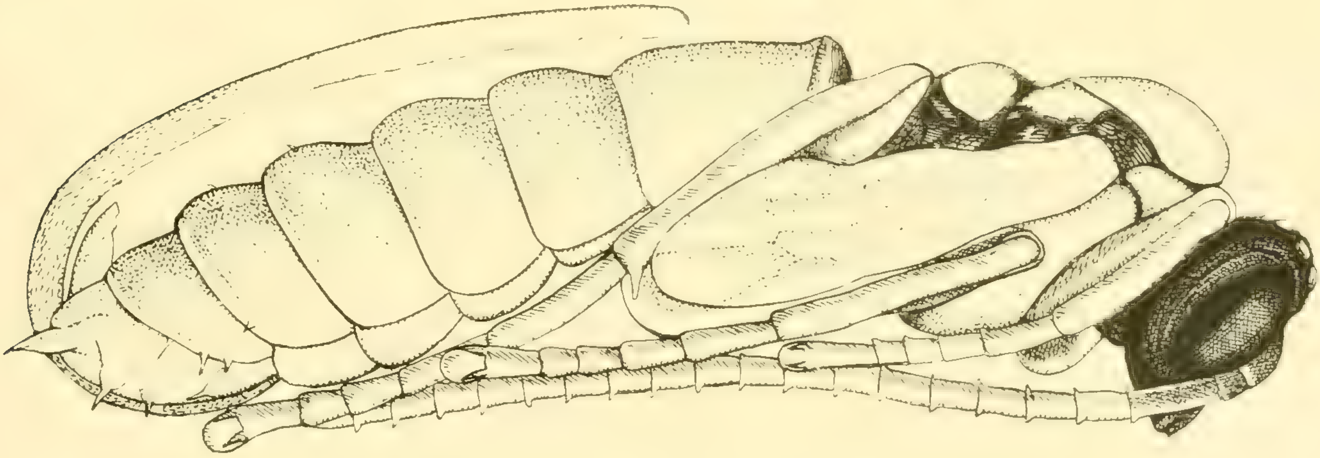

Fig 3

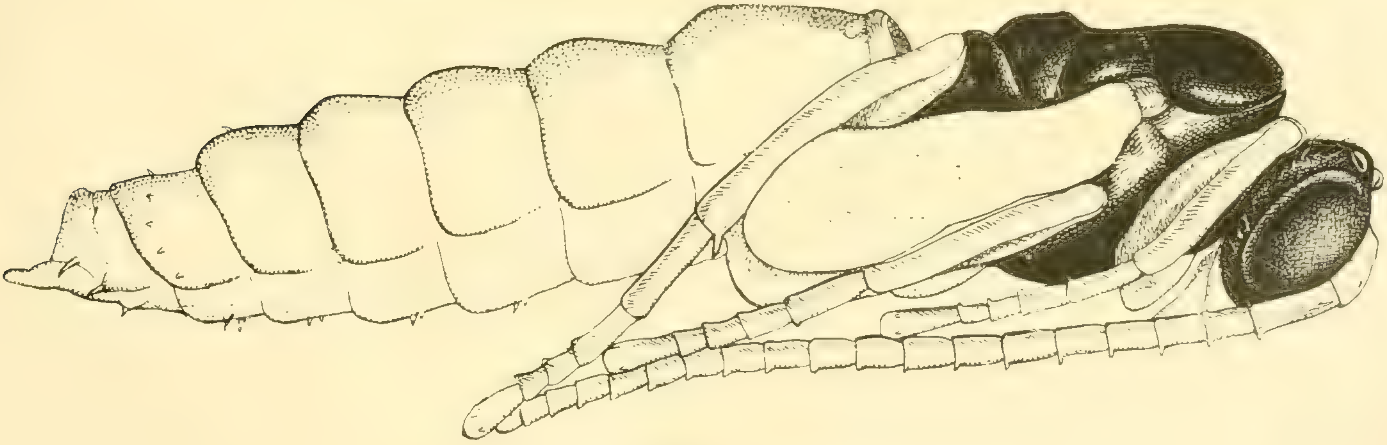

Fig. 4

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EXPLANATION OF PLATE XII.

Fig. 1. Young larva of *Pimpla pomorum* seen from the right side. × 62.

Fig. 2. Fully grown larva seen from the right side. × 26.

Fig. 3. Female pupa, lateral view. × 26.

Fig. 4. Male pupa, lateral view. × 26.

A LIST OF COCCIDAE AFFECTING VARIOUS GENERA OF PLANTS.

By E. ERNEST GREEN, F.E.S., F.Z.S.

(*Continued from page* 89)

DACRYDIUM (Coniferae).
  CTENOCHITON dacrydii.
DACTYLIS (Gramineae).
  PSEUDOCOCCUS walkeri.
  CEROPUTO volynicus.
  LUZULASPIS luzulae.
DAHLIA (Compositae).
  PSEUDOCOCCUS affinis.
  PULVINARIA psidii.
DALBERGIA (Leguminosae).
  MONOPHLEBUS dalbergiae, octocaudata.
  TACHARDIA lacca.
  LECANIUM expansum.
  ASPIDIOTUS trilobitiformis, lataniae, simillimus, transparens.
DALEA (Leguminosae).
  CEROPLASTODES daleae.
DAMMARA (Coniferae).
  PSEUDOCOCCUS aurilanatus.
DANAE (Liliaceae).
  FIORINIA pellucida.
DANTHONIA (Gramineae).
  ERIOCOCCUS danthoniae.
DAPHNE (Thymeliaceae).
  RHIZOCOCCUS gnidii.
  PSEUDOCOCCUS similans.
  LECANIUM magnoliarum.
  ASPIDIOTUS caldesii, hederae, camelliae, lataniae.
DASYLIRION (Bromeliaceae).
  LECANIODIASPIS yuccae.
  PSEUDOCOCCUS dasylirii.
DATURA (Solanaceae).
  PSEUDOCOCCUS virgatus.
  ASPIDIOTUS hederae.
DAVALLIA (Filices).
  HEMICHIONASPIS aspidistrae.
  LEPIDOSAPHES ocellata.
DAVIESIA (Leguminosae).
  PULVINARIA tecta.
  ASTEROLECANIUM stypheliae.
  CHIONASPIS nitida.
  POLIASPIS nitens.
  ASPIDIOTUS hederae.
  LEPIDOSAPHES casuarinae.
DEBREGAESIA (Urticaceae).
  PSEUDOCOCCUS debregaesiae.
  CEROPLASTES ceriferus.
  HEMICHIONASPIS mussaendae, minor.
DENDROBIUM (Orchidaceae).
  LEUCASPIS stricta.
  ASPIDIOTUS dictyospermi.
  LEPIDOSAPHES cocculi.
DENDROCALAMUS (Gramineae).
  ASTEROLECANIUM bambusae, coronatum.
  ANTONINA bambusae.
  CHIONASPIS angusta.
DENDROPHTHORA (Loranthaceae).
  PULVINARIA dendrophthorae.
DERRIS (Leguminosae).
  LEPIDOSAPHES dilatilobis.
DESCHAMPSIA (Gramineae).
  ERIOPELTIS festucae.
DESMANTHUS (Leguminosae).
  CERONEMA africana.
DEUTZIA (Philadelphaceae).
  ASPIDIOTUS perniciosus.
DEVERRA (Umbelliferae).
  CHIONASPIS bilobis.

DIANELLA (Liliaceae).
LEUCASPIS cockerelli.
PARLATORIA proteus.
DICHAPETALUM (Chailletiaceae).
ASPIDIOTUS maeandrius.
DICHOPSIS (Sapotaceae).
ICERYAE seychellarum.
VINSONIA stellifera.
DICTYOSPERMA (Palmaceae).
PINNASPIS buxi.
ASPIDIOTUS dictyospermi, articulatus, ficus.
DIELYTRA (Fumariaceae).
LECANIUM hesperidum.
DILLENIA (Dilleniaceae).
LECANIUM cocophyllae.
DILLWYNIA (Leguminosae).
LECANIUM pingue.
PULVINARIA contexta.
POLIASPIS exocarpi.
DIOON (Cycadaceae).
POLIASPIS cycadis.
DIASPIS zamiae.
DIOSCOREA (Dioscoreaceae).
ASPIDIOTUS hartii, destructor, transparens.
DIOSMA (Rutaceae).
LECANIUM oleae.
ASPIDIOTUS camelliae.
DIOSPYROS (Ebenaceae).
ICERYA seychellarum.
LECANIODIASPIS tessellata.
PHENACOCCUS pergandei.
CEROPLASTES ciripediformis.
PULVINARIA citricola.
LECANIUM corni, bicruciatum.
DIASPIS pentagona.
ASPIDIOTUS perniciosus, dictyospermi, duplex, aurantii, orientalis.
PARLATORIA pergandei-phyllanthi.
DIPTEROCARPUS (Dipterocarpaceae).
TACHARDIA lacca.
DIRCA (Thymeliaceae).
CHIONASPIS lintneri.
DISPORUM (Liliaceae).
ASPIDIOTUS hederae.
DISTICHLIS (Gramineae).
SPHAEROCOCCUS distichlium.
ERIOCOCCUS salinus.
DISTYLIUM (Hamamelideae).
CHIONASPIS latissima.
DOBERA (Salvadoraceae).
DINASPIS reticulata.
DODONAEA (Sapindaceae).
WALKERIANA senex.
PULVINARIA dodonaeae, thompsoni, psidii.
DOLICHOS (Leguminosae).
CEROPLASTODES cajani.
INGLISIA bivalvata.
LECANIUM longulum.
DOMBEYA (Sterculiaceae).
ICERYA jacobsoni.
DOODIA (Filices).
ALECANOPSIS filicum.
DORYCNIUM (Leguminosae).
ASTEROLECANIUM fimbriatum.
DOVYALIS (Flacourtiaceae).
HOWARDIA biclavis.
CEROCOCCUS ornatus.
DRABA (Cruciferae).
ASTEROLECANIUM fimbriatum.
DRACAENA (Liliaceae).
LECANIUM hesperidum.
HEMICHIONASPIS dracaenae, aspidistrae.
PINNASPIS buxi.
CHIONASPIS tangana.
ASPIDIOTUS lauretorum, tinerfensis, dictyospermi, lataniae, hederae.
LEUCASPIS cockerelli.
DRIMYS (Magnoliaceae).
INGLISIA patella.
PSEUDOPARLATORIA parlatorioides.
LEPIDOSAPHES drimydis.
DRYANDRA (Proteaceae).
CERONEMA dryandrae.
ASPIDIOTUS dryandrae.
PARLATORIA dryandrae.
DRYMUS.
ASPIDIOTUS moreirae, pisai.
DRYPETES (Euphorbiaceae).
LECANIUM hemisphaericum.
DURANTA (Verbenaceae).
PULVINARIA psidii.
LECANIUM oleae.
ORTHEZIA insignis.
DURIO (Malvaceae).
CHIONASPIS durionis.
DYSOXYLON (Meliaceae).
CHIONASPIS dysoxyli.

DYSOXYLON (Meliaceae)—*cont.*
- Aspidiotus dysoxyli.
- Lepidosaphes pyriformis.

EARINA (Orchidaceae).
- Ctenochiton elongatus.

ECHINOCACTUS (Cactaceae).
- Diaspis echinocacti.

ECHITES (Apocynaceae).
- Phenacoccus mangiferae.
- Aspidiotus trilobitiformis.

EDGEWORTHIA (Thymeliaceae).
- Pseudococcus edgeworthiae.

EHRETIA (Boragineae).
- Aspidiotus replicatus.

ELAEAGNUS (Elaeagnaceae).
- Lecanium bicruciatum, persicae, hesperidum, nigrofasciatum.
- Ceroplastes floridensis.
- Chionaspis difficilis, elaeagni, vitis.
- Diaspis crawii.
- Aspidiotus camelliae, britannicus, rossi.
- Aonidia elaeagni.
- Lepidosaphes citricola, crawii, ulmi.

ELAEIS (Palmaceae).
- Ceroplastes actiniformis.
- Hemichionaspis marchali.
- Aspidiotus elaeidis.
- Ischnaspis filiformis.

ELAEOCARPUS (Tiliaceae).
- Eriococcus pallidus.
- Pseudococcus scrobicularum.
- Lecanium formicarii.
- Eriochiton spinosus.
- Ctenochiton elaeocarpi, flavus.
- Inglisia ornata.
- Hemichionaspis scrobicularum.

ELAEODENDRON (Celastraceae).
- Fiorinia elaeodendri, plana.

ELAPHRIUM (Burseraceae).
- Ceroplastes ceriferus.

ELLIPANTHUS (Connaraceae).
- Chionaspis vitis.

ELYMUS (Gramineae).
- Ripersia smithii.

ELYTROPAPPUS (Compositae).
- Sphaerococcus africanus.
- Pseudococcus elizabethae.

EPACRIS (Epacridaceae).
- Eriococcus multispinosus-laevigatus.
- Lecaniodiaspis microcribraria.

EPHEDRA (Gnetaceae).
- Pseudococcus ephedrae.
- Lichtensia ephedrae.
- Philephedra ephedrae.
- Stotzia striata.
- Filippia ephedrae.
- Dinaspis ichesii.
- Leucaspis ephedrae.
- Aspidiotus trabuti, ephedrarum.
- Parlatoria ephedrae.

EPIDENDRUM (Orchidaceae).
- Asterolecanium epidendri.

EPIGAEA (Ericaceae).
- Aspidiotus epigaeae.

ERANTHEMUM (Acanthaceae).
- Icerya seychellarum, sulfurea.
- Lecanium hemisphaericum, depressum.
- Pulvinaria jacksoni.

EREMOPHILA (Myoporaceae).
- Aspidiotus coralinus, hederae.

ERICA (Ericaceae).
- Orthezia maenariensis, urticae.
- Asterolecanium fimbriatum.
- Eriococcus devoniensis, ericae.
- Ripersia halophila.
- Pseudococcus ericicola.
- Pulvinaria ericae.
- Lecanium oleae, hemisphaericum.
- Diaspis ericicola.
- Chionaspis salicis.
- Adiscodiaspis ericicola.
- Aspidiotus hederae, bavaricus.
- Lepidosaphes ulmi.

ERIGERON (Compositae).
- Pseudococcus neomexicanus.
- Ceroplastes cultus, cuneatus.

ERIOBOTRYA (Rosaceae).
- Icerya purchasi.
- Ceroplastes vinsonii.
- Diaspis pentagona.
- Aspidiotus dictyospermi, aurantii.
- Parlatoria oleae, pergandei.

ERIODENDRON (Malvaceae), 'Silk Cotton.'
- Aspidoproctus giganteus.
- Lecanium intimum, nigrum.

- ERIODENDRON (Malvaceae)—*cont.*
  - Aspidiotus pedroniformis.
- ERIODICTYON (Hydrophyllaceae).
  - Pseudococcus yerba-santae.
- ERIOGONUM (Polygonaceae).
  - Eriococcus palmeri, eriogoni.
  - Pseudococcus maritimus.
  - Erium eriogoni.
- ERYTHEA (Palmaceae).
  - Comstockiella sabalis.
  - Hemichionaspis aspidistrae.
- ERYTHRASPIS.
  - Aspidiotus camelliae, erythraspidis.
- ERYTHRINA (Leguminosae).
  - Pseudococcus crotonis.
  - Lecanium tenebricophilum, oleae.
  - Pulvinaria maxima.
  - Eriochiton theae.
  - Diaspis pentagona.
  - Aspidiotus dictyospermi, pustulans.
  - Lepidosaphes erythrinae.
- ERYTHROPALUM (Olaeaceae).
  - Lecanium cocculi.
- EUCALYPTUS (Myrtaceae).
  - Monophlebus fortis, crawfordi, crawfordi-levis, crawfordi-pilosior.
  - Gueriniella serratulae.
  - Callipappus australis, immanis.
  - Apiomorpha attenuata, bauerleni, calycina, conica, duplex, minor, ellipsoides, floralis, helmsii, karschi, maliformis, munita, munita-tricornis, ovicola, ovicola-glabra, ovicoloides, pedunculata, pharetrata, pileata, pomiformis, rosaeformis, rugosa, sessilis, sloanei, strombylosa, thorntoni, thorntoni-nux, umbellata, urnalis, variabilis, urnalis-schraderi, cucurbita, dipsaciformis, excupula, fletcheri.
  - Opisthoscelis conica, fibularis, globosa, maculata, mammularis, maskelli, nigra, pisiformis, serrata, spinosa, subrotunda, verrucula.
  - Ascelis attenuata, echiniformis, praemollis, schraderi.
  - Warburtonia frenchi.
  - Lecaniodiaspis eucalypti, frenchi, convexus, newmani.
  - Gossyparia confluens.
  - Eriococcus confusus, coriaceus, eucalypti, simplex, simplex-dealbata, tepperi, tricarinatus, serratilobis, crofti, apiomorphae, gregarius, irregularis, picta, tessellatus.
  - Sphaerococcus elevans, obscuratus, pustulans.
  - Sphaerococopsis inflatipes.
  - Ourococcus cobbii, eucalypti.
  - Lachnodius eucalypti, lectularius.
  - Pseudococcus lobulatus.
  - Tachardia melaleucae.
  - Lecanium oleae.
  - Ctenochiton eucalypti.
  - Ceronema caudata.
  - Pulvinaria maskelli.
  - Chionaspis assimilis, ethelae, eugeniae, formosa, eucalypti, frenchi, angusta.
  - Aspidiotus extensus, perniciosus, camelliae, subrubescens, rossi, acaciae, eucalypti, alatus, confusus, rubribullata, subrubescens-corticoides, rossi-victoriae, fuscus, tasmaniae, miniatae, ficus, amplius, cyanophylli, articulatus, personatus.
  - Maskellia globosa.
  - Lepidosaphes cordylinidis, grisea, lidgetti, bicornis, eucalypti, bicornis-alba.
  - Fiorinia lidgetti.
- EUCHARIS (Amaryllidaceae).
  - Asterolecanium aureum.
  - Hemichionaspis minor.
- EUGENIA (Myrtaceae).
  - Llaveia primitiva-pimentae.
  - Capulinia jaboticabae, crateriformans.
  - Erioides cuneiformis.
  - Carpochloroides viridis.
  - Stictolecanium ornatum.
  - Lecanium tessellatum, jaboticabae, bicruciatum, psidii, mangiferae.
  - Pulvinaria eugeniae, psidii, grabhami.
  - Ceroplastes fairmairii, formosus, rubens.
  - Vinsonia stellifera.

EUGENIA (Myrtaceae)—*cont.*
Edwallia rugosa.
Chionaspis eugeniae.
Fiorinia fioriniae.
Aspidiotus fimbriatus, virescens, hederae, ficus, camelliae, destructor, personatus.
Odonaspis pimentae.
Lepidosaphes rubrovittatus, ungulata.
Parlatoria oleae, proteus.
EUONYMUS (Celastraceae).
Lecanium oleae, coryli, nigrofasciatum, capreae.
Pulvinaria camelicola, euonymi, innumerabilis, betulae, floccifera.
Diaspis pentagona.
Chionaspis citri, euonymi, acuminata, salicis.
Aspidiotus euonymi, perniciosus, aurantii, rossi, camelliae, dictyospermi, ficus, lataniae.
Parlatoria theae-euonymi.
EUPATORIUM (Compositae).
Orthezia insignis.
Asterolecanium fimbriatum.
EUPHORBIA (Euphorbiaceae).
Palaeococcus rosae.
Icerya euphorbiae.
Walkeriana euphorbiae.
Orthezia urticae.
Asterolecanium fimbriatum.
Pseudococcus virgatus, longispinus.
Lecanium longulum.
Ceroplastes euphorbiae.
Cerococcus alluaudi.
Diaspis conservans, barrancorum, antiquorum.
Aspidiotus trilobitiformis-darutyi, ferox, magnus, euphorbiae, fissus, taorensis, lenticularis, biformis, hederae.
Cryptaspidiotus austroafricanus.
Lepidosaphes ulmi.
Parlatoria mangiferae.
EUPHRASIA (Scrophulariaceae).
Asterolecanium fimbriatum.
EURYA (Ternstroemiaceae).
Lecanium ochnaceae.
Pulvinaria aurantii, psidii.
EURYA (Ternstroemiaceae)—*cont.*
Aspidiotus duplex.
Lepidosaphes euryae.
EURYCLES (Amaryllidaceae).
Chionaspis dilatata.
EUTERPE (Palmaceae).
Diaspis boisduvallii.
EVODIA (Rutaceae).
Chionaspis acuminata.
Dinaspis permutans.
EXCOECARIA (Euphorbiaceae).
Lecanium longulum.
Ceroplastes excoecariae.
EXOCARPUS (Thymeliaceae).
Cerococcus bryoides, bryoides-stellatus.
Pseudococcus hibbertiae.
Ceroplastodes melaleucae.
Poliaspis exocarpi.
Aspidiotus junctlobius.
Lepidosaphes casuarinae, subspiculifera.
FABIANA (Solanaceae).
Pulvinaria argentina.
Ceroplastes longiseta.
Aspidiotus fabianae.
FAGONIA (Zygophyllaceae).
Aspidiotus nigra, hederae.
FAGRAEA (Loganiaceae).
Lecanium psidii.
Diaspis fragraeae.
FAGUS (Corylaceae) ‘Beech.’
Coelostomidia assimilis, pilosa.
Phenacoleachia zealandica.
Cerococcus fagi.
Fagisuga triloba.
Platypyga fagi.
Eriococcus fagicorticis, pallidus, raithbyi, aceris.
Rhizococcus intermedius, maculatus, pulchellus, totarae, cavellei.
Cryptococcus fagi.
Pseudococcus iceryoides, obtectus, aceris, newsteadi.
Ripersia fagi.
Pulvinaria innumerabilis, betulae.
Inglisia fagi.
Aspidiotus ancylus, forbesi, ostreiformis, perniciosus.
Lepidosaphes ulmi.

FATSIA (Araliaceae).
Pulvinaria psidii.
Protopulvinaria japonica.
FERONIA (Rutaceae).
Anomalococcus cremastogastri.
FESTUCA (Gramineae).
Eriococcus festucae.
Ripersia festucae.
Trionymus californicus.
Eriopeltis festucae, lichtensteinii.
FICUS (Moraceae).
Aspidoproctus verrucosus.
Drosicha maskelli, lichenoides.
Monophlebus octocaudata.
Icerya aegyptiaca, maxima, purchasi, seychellarum.
Gueriniella serratulae.
Tachardia lacca, fici, longisetosa.
Asterolecanium pustulans.
Lecaniodiaspis africana.
Anomalococcus cremastogastri.
Eriococcus crispus, lagerstroemiae.
Pseudococcus ficus, longispinus, setosus, adonidum, citri, crotonis, virgatus, virgatus-madagascariensis.
Phenacoccus mangiferae.
Stictococcus formicarii.
Lecanium ficus, longulum, depressum, nigrella, plebeium, nigrum, ficinum, oleae, persicae, tessellatum, crassum, hesperidum, desolatum, hemisphaericum, formicarii, expansum, expansum-javanicum, ramakrishnae, carpenteri.
Hemilecanium imbricans.
Pulvinaria ficus, psidii, psidii-philippina, jacksoni, cupaniae.
Lichtensia lutea.
Ceroplastes floridensis, rubens, rusci, townsendi-percrassus, ficus, quadrilineatus, gowdeyi, coniformis, ceriferus, galeatus.
Diaspis gennadii.
Schizaspis lobata.
Chionaspis manni, fici.
Howardia biclavis.
Hemichionaspis aspidistrae, minor, fici, minima.
Leucaspis japonica.
FICUS (Moraceae)—*cont.*
Aspidiotus cyanophylli, cydoniae, camelliae, trilobitiformis, articulatus, ficus, aurantii, africanus, sylvatica, fossor, obsita, orientalis, dictyospermi, personatus, lataniae.
Aonidia planchonioides.
Gymnaspis ficus.
Lepidosaphes citricola, ficus, ficifolii, mexicana, minima, pinniformis, conchiformis, luzonica.
Ischnaspis filiformis.
FILICES ‘Ferns.’
Tessarobelus guerinii.
Orthezia cheilanthi.
Eriococcus insignis.
Macrocerococcus superbus.
Pseudococcus longispinus.
Ripersia filicicola.
Lecanium tessellatum, hesperidum-alienum, cockerelli, filicum, hemisphaericum, mori, diversipes, oleae, longulum.
Pulvinaria mammeae, floccifera.
Ceroplastes rubens.
Ctenochiton depressus.
Alecanopsis filicum.
Chionaspis dilatata, dubia.
Hemichionaspis aspidistrae.
Poliaspis media.
Lepidosaphes phymatodidis, ocellata, desmidioides.
FILICIUM (Burseraceae).
Tachardia albizziae.
FLACOURTIA (Flacourtiaceae).
Pseudococcus longispinus.
Diaspis pentagona-flacourtiae.
Howardia biclavis.
Parlatoria cingala.
FOUQUIERIA (Tamaricaciae).
Lecaniodiaspis rufescens.
FRAGARIA (Rosaceae) ‘Strawberry.’
Icerya genistae.
Orthezia insignis.
Diaspis rosae.
Aspidiotus perniciosus.
FRAXINUS (Oleaceae) ‘Ash.’
Fonscolombia fraxini.
Phenacoccus aceris, pettiti.

- FRAXINUS (Oleaceae)—*cont.*
  - Lecanium cerasifex, fraxini, oleae, nigrofasciatum, corni, robiniae-subsimile.
  - Pulvinaria fraxini, betulae.
  - Ericerus pela.
  - Diaspis pentagona.
  - Chionaspis salicis.
  - Aspidiotus ancylus, juglansregiae-albus, perniciosus, townsendi, vagabundus, pyri.
  - Lepidosaphes ulmi.
  - Parlatoria oleae, affinis.
- FRENELLA (Coniferae).
  - Erium frenellae.
- FREYCINETIA (Pandanaceae).
  - Pseudococcus montanus.
- FUCHSIA (Onagraceae).
  - Pseudococcus citri, longispinus.
  - Ceroplastes albolineatus.
  - Aspidiotus camelliae.
  - Lepidosaphes lactea.
- FUMARIA (Papaveraceae).
  - Macrocerococcus superbus.
  - Ceroputo superbus.
- FUNTUMIA (Apocynaceae).
  - Pulvinaria psidii.
  - Ceroplastes ceriferus.
  - Chionaspis funtumiae, lutea.
- FURCRAEA (Amaryllidaceae).
  - Lecanium hesperidum, depressum.
  - Aspidiotus furcraeicola, hederae.

- GAERTNERA (Loganiaceae).
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  - Chionaspis varicosa.
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Essays by Cambridge Graduates
with an Introduction by the
Right Hon. Lord Moulton, K.C.B., F.R.S.

Edited by A. C. SEWARD, F.R.S., Master of Downing College, Cambridge.

It is the aim of the authors of these essays to present the results of experience in scientific investigation, to illustrate by concrete examples the sources of progress in a few departments of knowledge and so make clear to the layman the position of research as a factor in national prosperity. Each Essay has been written by some one who, by lifelong study and practice of the Branch of Science to which it relates, has qualified himself to give a just and authoritative description of the work that has already been done as well as of the bearing of that work on the present and its promise for the future.

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